FINAL

LIFAC DEMONSTRATION

AT
RICHMOND POWER AND LIGHT

WHITEWATER VALLEY UNIT No. 2

FINAL REPORT VOLUME 1: PUBLIC DESIGN

Sponsored by:

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ABSTRACT

This report discusses the demonstration of LIFAC sorbent injection technology at Richmond Power and Light's (RP&L) Whitewater Valley Unit No. 2 under the auspices of the U.S. Department of Energy's (DOE) Clean Coal Technology Program. LIFAC is a sorbent injection technology capable of removing 75 to 85 percent of a power plant's SO_2 emissions using limestone at calcium to sulfur molar ratios of between 2 and 2.5. The site of the demonstration is a coal-fired electric utility power plant located in Richmond, Indiana. The project is being conducted by LIFAC North America (LIFAC NA), a joint venture partnership of Tampella Power Corporation and ICF Kaiser Engineers, in cooperation with DOE, RP&L, and several other organizations including the Electric Power Research Institute (EPRI), the State of Indiana, and Black Beauty Coal Company. The purpose of *Final Report Volume 1: Public Design* is to consolidate, for public use, all design and cost information regarding the LIFAC Desulfurization Facility at the completion of construction and startup. This report has been prepared pursuant to Cooperative Agreement No. DE-FC22-90PC90548 between LIFAC NA and the U.S. Department of Energy.

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$CaCO_3$	Calcium carbonate
CaO	Calcium oxide
$CaSO_3$	Calcium sulfite
$CaSO_4$	Calcium sulfate
$Ca(OH)_2$	Calcium hydroxide, hydrated lime
Ca/S	Calcium/sulfur molar ratio, (moles of Ca in sorbent/moles of S in inlet flue gas stream)
CCT	Clean Coal Technology
DOE	U.S. Department of Energy
EER	Energy and Environmental Research Corporation
EPRI	Electric Power Research Institute
ESP	Electrostatic precipitator
FGD	Flue gas desulfurization
ICF Kaiser	ICF Kaiser Engineers, Inc.
ID fan	Induced draft fan
LIFAC	Limestone Injection into the Furnace with Activation of unreacted Calcium oxide, registered trademark of Tampella desulfurization process
LIFAC NA	LIFAC - North America (partnership)
LIMB	Lime Injection to Multistage Burner (registered trademark of EPA desulfurization process)
LNCFS	Low-NO_x Concentric Firing System
$MgCO_3$	Magnesium carbonate
MW	Megawatt
NO	Nitric oxide
NO_x	Nitrogen oxides
O_2	Oxygen
PLC	Programmable logic controller
PMS	Process monitoring system
RP&L	Richmond Power & Light
SCA	Specific collection area
SO_2	Sulfur dioxide
SO_3	Sulfur trioxide

ΔT	Temperature difference between actual flue gas temperature and saturation temperature (approach to saturation)
USEPA	U.S. Environmental Protection Agency
Injection	Pulverized limestone injection into the furnace through several injection nozzles at the furnace walls
Activation	Activation of the remaining CaO particles with water for further sulfur dioxide capture
Recycling	Recycling of ash and sorbent from ESP hoppers to the reactor inlet ductwork.

0.0 EXECUTIVE SUMMARY

The Clean Coal Technology Program (CCT) has been recognized in the National Energy Strategy as a major initiative whereby coal will be able to reach its full potential as a source of energy for the nation and the international marketplace. Attainment of this goal depends upon the development of highly efficient, environmentally sound, competitive coal utilization technologies responsive to diverse energy markets and varied consumer needs. The CCT Program is an effort jointly funded by government and industry whereby the most promising advanced coal-based technologies are being moved into the marketplace through demonstration. The CCT Program is being implemented through a total of five competitive solicitations.

LIFAC North America, a joint venture partnership of ICF Kaiser Engineers, Inc. and Tampella Power Corporation, recently completed the demonstration of the LIFAC flue gas desulfurization (FGD) technology developed by Tampella Power. This technology provides sulfur dioxide (SO_2) emission control for power plants, especially in existing facilities with tight space limitations. SO_2 emissions are expected to be reduced by up to 85% by using limestone as a sorbent. The LIFAC technology was demonstrated at Whitewater Valley Unit No. 2, a 60-MWe coal-fired power plant owned and operated by Richmond Power and Light (RP&L) and located in Richmond, Indiana. The Whitewater plant consumes high-sulfur coals, with sulfur contents ranging from 2.0-2.9 %.

The project, co-funded by LIFAC North America and DOE, was conducted with the participation of RP&L, the State of Indiana, the Electric Power Research Institute (EPRI), and the Black Beauty Coal Company. The project has a total cost of $21.4 million and a duration of 48 months from the preliminary design phase through the testing program.

The sponsors of this project believed that LIFAC had the potential to be a new and important SO_2 control option for U.S. utilities subject to the Clean Air Act's acid rain regulations. To be considered as a commercially feasible option in this particular emissions control market, LIFAC must demonstrate a high SO_2 removal rate while remaining competitive with other options on a cost per ton of SO_2 removed basis.

The LIFAC system combines conventional limestone injection into the upper furnace region with a post-furnace humidification reactor located between the air preheater and the electrostatic precipitator (ESP). The process produces a dry, stable waste product that is removed from both the bottom of the humidification reactor and the ESP.

Finely pulverized limestone (80% < 325 mesh) is pneumatically conveyed and injected into the upper region of the boiler where temperatures are approximately 1,800 to 2,200 ° Fahrenheit. At these temperatures the limestone ($CaCO_3$) thermally decomposes to form calcium oxide (CaO). As the CaO passes through the furnace, initial desulfurization reactions occur. A portion of the sulfur dioxide (SO_2) reacts with the CaO to form calcium sulfite ($CaSO_3$) which oxidizes to calcium sulfate ($CaSO_4$). Essentially all of the sulfur trioxide (SO_3) reacts with CaO to form $CaSO_4$.

At an overall SO_2 removal efficiency of 75%, approximately 25% of the SO_2 is removed in the boiler, with an additional 50% removed after the unreacted lime has passed through the vertical elongation of ductwork known as the LIFAC activation reactor. There the flue gas is sprayed with atomized water that allows the unreacted lime to hydrate to $Ca(OH)_2$ which more readily reacts with SO_2 and forms $CaSO_3$. A combination of the proper water droplet size and residence time allows for effective hydration of the lime and complete water evaporation to create a dry reactor bottom product.

After exiting the humidification reactor, the flue gas is reheated before entering the ESP. Forty % of the LIFAC-produced spent sorbent and fly ash is collected in the humidification reactor with the remaining 59.9% collected by the ESP. The LIFAC system can be designed so that both the reactor and ESP ash may be recycled to a point ahead of the reactor to improve sorbent utilization and to improve SO_2 removal efficiency to the range of 75 to 85%.

LIFAC is similar to other current sorbent injection technologies but has unique advantages with its use of a patented vertical humidification reactor. While LIFAC's SO_2 removal efficiency is not as high as traditional wet FGD systems, its cost and simplicity of design, construction and operation offer other advantages over alternative systems. In particular the advantages of the LIFAC system are:

- High SO_2 removal rates - Currently available sorbent injection systems have been unable to sustain high SO_2 removal rates with any consistency. LIFAC has proven in the past and is demonstrating during this project the ability to achieve and sustain high SO_2 removal rates of 75 to 85% over long operating periods.

- Dry by-products - Wet lime and limestone scrubbing systems create a wet by-product ash that must be further treated before disposal. LIFAC produces a dry solid waste ash containing calcium sulfite, calcium sulfate and fly ash. This waste is easily disposed of under U.S. regulatory requirements, may be recycled to increase LIFAC's efficiency, and may have commercial applications in the construction material industry.

- Compatibility and adaptability - LIFAC has minimal impact on the host's site and systems, primarily the boiler, ESP and induced draft (ID) fan. In addition, LIFAC requires little space and few utilities and, therefore, is easily installed even in small or cramped power plant sites.

Construction of the LIFAC system has occurred in two phases over a period of one and a half years. The first phase of construction was completed during a routine plant outage in March 1991. This period was utilized to install tie-ins to the host site's existing systems.

Ductwork and three dampers were installed between the air preheater and ESP to allow flue gas flow to the LIFAC activation reactor. Tie-ins were also made to the power plant's steam, condensate and river-water supplies. Medium-pressure steam is used to reheat the flue gas exiting the LIFAC reactor, and water is used for flue gas humidification inside the reactor. Injection ports were installed in the boiler walls about 10 feet above the nose elevation.

The second phase of construction began in the fall of 1991 with the driving of piles for the reactor and the installation of underground conduit runs. Work continued through to the summer of 1992, with no need for plant downtime other than normally scheduled outages. During this time, the limestone storage area was completed, and the injection system was installed on Unit No. 2. The activation reactor was constructed and tested with both cold air, during a scheduled Unit No. 2 outage, and hot flue gas during a low electricity demand period. Other power plant tie-ins, such as the steam and condensate system, were also tested during low demand periods in the evenings or on weekends.

All of the construction work associated with the LIFAC system was performed in close proximity to the exterior of the power plant or in cramped areas inside the plant. The ductwork tie-ins and new steel work required inside the plant are located in small, difficult-to-access work areas. The reactor structure is approximately ten feet from the power plant with the outside ductwork and piping crossing over offices and the plant maintenance area. All of these new structures and equipment were constructed with no interference to daily plant operations.

The schedule for the LIFAC demonstration program extended over a four-year period from the beginning of preliminary design in August 1990 through the testing program completed in early August 1994. The LIFAC system was originally scheduled to come on-line in June of 1992, but due to delays in receiving construction permits and some minor startup problems, this date was moved to March 1993. Testing was then scheduled to continue through the summer of 1994.

The test plan for the LIFAC demonstration is composed of five distinct phases, each with its own objective. The first of these phases consists of the initial baseline testing portion of the project. Measurements were taken to characterize the operation of the host's boiler and associated subsystems prior to the use of the LIFAC system. The results were used for comparison purposes with the LIFAC system in operation and with data collected at the end of the project to determine any changes in the host's systems.

The second, or parametric, phase of testing was performed to determine the best combination of LIFAC process variables for SO_2 removal. The variables studied included the limestone injection nozzles' angle and location, the Ca/S molar ratio, the need for supplemental injection air at the boiler, the water droplet size and injection nozzle arrangement in the reactor, the ash recycling ratio, and the approach to saturation temperature of the flue gas exiting the activation reactor. The best combination of these variables was chosen at the conclusion of this phase and used for the remainder of the test program.

Parametric tests were also conducted to examine the effects of different coal and limestone feeds on the SO_2 capture rate. Coals with sulfur contents as high as 3.3% were tested to determine LIFAC's compatibility with high sulfur U.S. coals. Limestones of different sizes were also tested to determine the LIFAC system's adaptability to local sorbent sources.

Optimization and long-term testing were also performed to demonstrate LIFAC's performance under commercial conditions. The LIFAC system was in operation 24 hours per day for several weeks using the power plant's baseline coal, high calcium limestone, and the optimum combination of process variables. In addition to process performance measurements, during this phase the operation and maintenance requirements of the system were examined. Long-term (two to three weeks) tests were also conducted with two other coals; one lower sulfur coal (1.5%) and one higher sulfur content coal (3.3%).

The final phase of testing was the post-LIFAC tests. The baseline tests were repeated to gather information on the condition of the boiler and its associated subsystems. Comparisons were made to the original baseline data to identify any changes either caused by the LIFAC system or independent of its operation.

It has also been shown at RP&L and other LIFAC installations that the system can be installed without affecting normal power plant operations. The demonstration showed that the system can economically reduce SO_2 emission when compared with other FGD technologies.

1.0 PROJECT OVERVIEW

1.1 Purpose of the Public Design Report

The purpose of this Public Design Report is to provide design criteria and cost information on the LIFAC desulfurization process at the completion of construction and startup. The report serves as a reference for the demonstration technology and its future commercialization. Final Report Volume 1: Public Design has been prepared pursuant to Cooperative Agreement No. DE-FC222-90PC90548 between LIFAC North America (LIFAC NA) and the U.S. Department of Energy (DOE) titled "LIFAC Demonstration at Richmond Power and Light (RP&L) Whitewater Valley Unit No. 2."

1.2 Brief Description of the Project

1.2.1 Project History

In 1983, Finland enacted acid rain legislation which applied limits on SO_2 emissions sufficient to require that flue gas desulfurization (FGD) systems have the capability to remove about 80% of the SO_2 in the flue gas. This level could be met by conventional wet limestone scrubbers but not by then available sorbent injection technology. Tampella, therefore, began developing an alternative sorbent injection system which resulted in the LIFAC process.

In 1986, the first full scale test was performed at Imatran Voima's Inkoo power plant using a 70 megawatt (MW) side-stream from a 250 MW boiler. A 76% SO_2 removal rate with 1.5% sulfur coal was reached. A second LIFAC activation reactor was constructed to handle an additional 125 MW side-stream. This newer reactor is achieving removal rates of 75 to 80% while using Ca/S molar ratios of between 2 and 2.5 to 1. Also in 1988, the first tests with high sulfur U.S. coals were run at the Neste Kullo Laboratory. A Pittsburgh No. 8 Seam coal containing 3% sulfur was tested and a SO_2 removal rate of 77% was achieved at a Ca/S molar ratio of 2 to 1.

DOE has emphasized the use and further development of coal as an energy source for utilities and the industrial sector. At the same time, environmental responsibility has been mandated by the passage of the Clean Air Act Amendments of 1990. This Act establishes new lower emission levels of SO_2 from utility power plants, with Phase I of the regulations having come into effect in January 1995, and the more stringent Phase II regulations beginning in January 2000. To realize full potential of coal as an energy source while still complying with the new air pollution regulations, the DOE initiated the Clean Coal Technology (CCT) Program.

The Clean Coal Technology (CCT) Program is a jointly funded government-industry effort to select the most promising advanced coal-based technologies and, over the next decade, move them into the commercial marketplace through demonstration. These demonstrations are conducted at a scale large enough to generate the data from design, construction, and operation that is necessary for the private sector to judge commercial potential and to make informed and confident decisions on commercial readiness.

The goal of the program is to make available to the U.S. energy marketplace, particularly the industrial and utility sectors, a number of advanced, more efficient, and environmentally responsive coal technologies. These technologies will reduce and/or eliminate the economic and environmental impediments that limit the full consideration of coal as a future energy resource. The program is being implemented through a series of five competitive solicitations which are now completed. Selections for the fifth solicitation were made in May 1993. Federal funding of $2.75 billion is committed for the five rounds of the program. When the private sector cost share is included, total funding approaches $7 billion. When the program is completed, clean coal technology options that will reduce the uncertainties of subsequent commercial-scale applications.

The intent as well as the objective of the DOE, as related to coal, has been endorsed most recently in the language of the Energy Policy Act of 1992 (Public Law 102-486). This legislation identifies a number of energy goals which already are a key part of the CCT Program, including achieving greater efficiencies in the conversion of coal to useful energy; achieving control of sulfur oxides, oxides of nitrogen, air toxics, solid and liquid wastes, greenhouse gases, or other emissions resulting from coal use; and promoting the export and transfer of U.S. clean coal technologies and services to developing countries and countries making the transition to free market economies.

CCT projects seek to demonstrate the commercial feasibility of the most promising advanced coal technologies that have already reached the proof-of-concept stage. These projects are conducted under jointly funded cooperative agreements-not contracts-between government and industry. The industrial partner in each project contributes at least 50% of the total cost-in many cases, more-and the patent rights for inventions developed during the demonstrations are normally granted to the participant. Each project involves a technology that the industrial partner believes has very real commercial potential. The program preserves incentives the industrial partner needs to subsequently bring the technology into the marketplace.

The emphasis in the program has evolved through the five rounds. Clean Coal I covered a broad range of advanced technologies. Clean Coal II focused on technologies to reduce acid rain precursors, especially those that can be applied to existing facilities using high-sulfur coal. Clean Coal III expanded the scope of the Clean Coal II solicitation to include coal-based technologies that help to meet future energy demands in an environmentally acceptable manner. Clean Coal IV included technologies to address similar needs in new as well as existing plants. The emphasis on high efficiency and high environmental performance has increased in each successive round of the program. Clean Coal V gave significant credit to projects that offer increased efficiency and environmental performance.

The LIFAC system was one of thirteen projects selected for funding under Round III of the CCT Program. A Cooperative Agreement between DOE and LIFAC NA was signed in November 1990. Due to scheduled outages at the host site, RP&L's Whitewater Valley Unit No. 2 in Richmond, Indiana, design and procurement of critical equipment began in August 1990, with DOE funding contingent on final signing of the Cooperative Agreement.

1.2.2 Project Organization

The LIFAC demonstration was conducted by LIFAC NA, a joint venture partnership between ICF Kaiser Engineers, Inc. (ICF Kaiser) and Tampella Power Corporation. ICF Kaiser is a U.S. company based in Oakland, California, and a subsidiary of ICF Kaiser International, Inc., based in Fairfax, Virginia. Tampella Power is a subsidiary of a large diversified international company, Tampella Corporation, which is based in Tampere, Finland, and the original developer of the LIFAC technology.

LIFAC NA is responsible for the overall administration of the project and for providing the 50% matching funds. With the exception of project administration, most of the actual work is being performed by the two parent firms under service agreements with LIFAC NA. Both parent firms work closely with RP&L and the other project team sponsors, including ICF Resources, EPRI, Indiana Corporation for Science and Technology (ICS&T), and Black Beauty Coal Company. ICF Kaiser managed the demonstration project out of its Pittsburgh office, which provided excellent access to DOE representatives at the Pittsburgh Energy Technology Center. A project organization chart is provided in Figure 1-1.

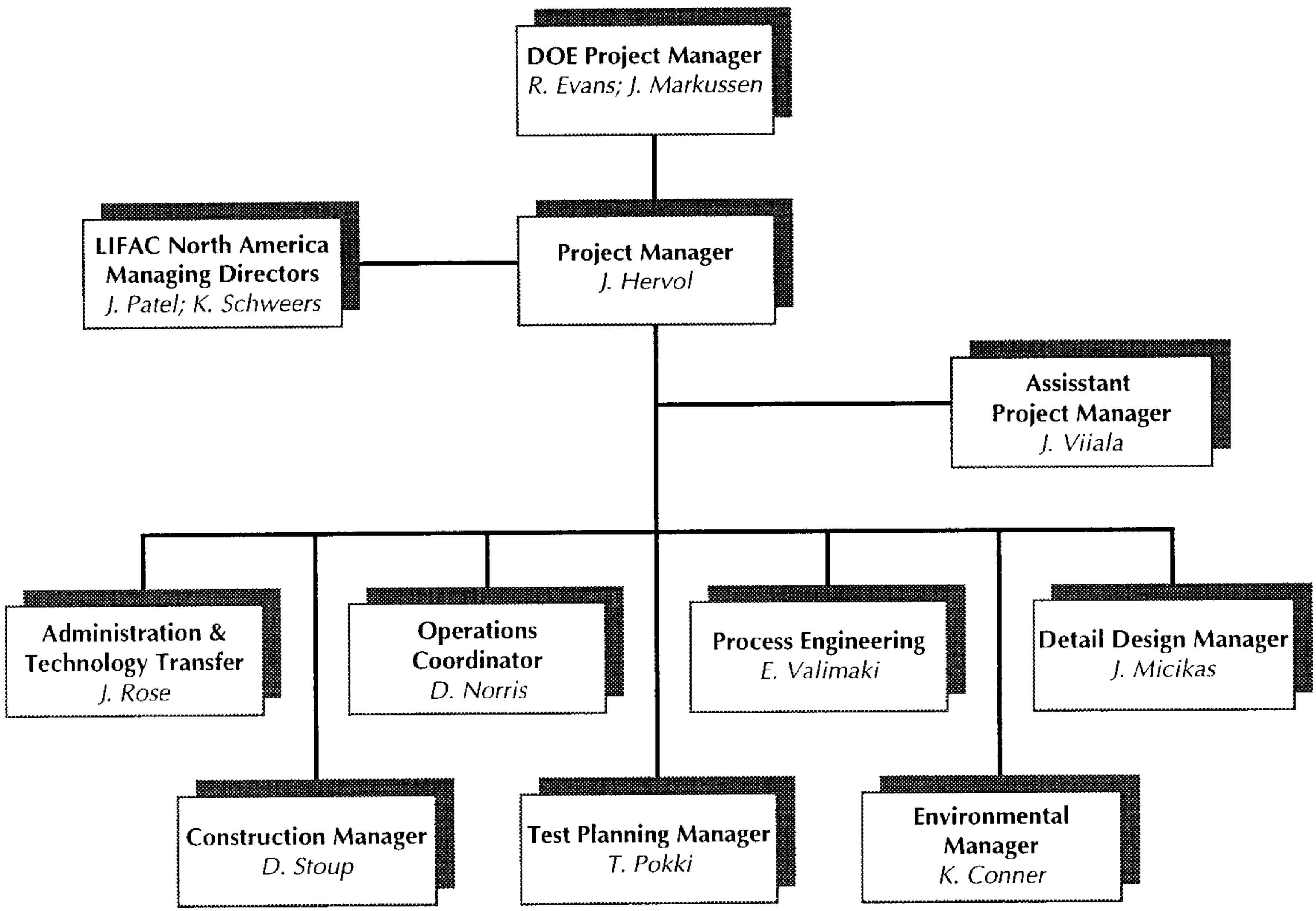
1.2.3 Host Site

The project site for the LIFAC demonstration is RP&L's Whitewater Valley Unit No. 2 pulverized coal-fired power station (60 MW), located in Richmond, Indiana. Richmond is approximately 75 miles east of Indianapolis, Indiana, and nearly 40 miles west of Dayton, Ohio. Whitewater Valley Unit No. 2, which began service in 1971, is a Combustion Engineering, tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Actual power produced by the unit approaches 65 MW. As such, it is one of the smallest existing, tangentially-fired units in the United States. The furnace is 26-feet, 11-inches deep and 24-feet, 8-inches wide and has a primary and secondary superheater. Tube sizes and spacings are designed to achieve the highest possible heat-transfer rates with the least potential for gas-side fouling. The unit also has an inherent low draft-loss characteristic because of the lack of gas turns. At full load, 540,000 lbs/hr of steam are generated. The heat input at rated capacity is 651×10^6 Btu per hour. The design superheater outlet pressure and temperature are 1,320 psi at 955°F. The unit has a horizontal shaft basket-type air preheater. The flue gas temperature leaving the economizer is about 645°F, while the flue gas temperature after the air preheater is about 316°F. The balanced-draft unit has 12 burners.

In 1980 the unit was fitted and fully optimized with a state-of-the-art Low-NO_x Concentric Firing System (LNCFS). The LNCFS represents a very cost-effective means of reducing NO_x emissions in comparison with other retrofit possibilities. The system works on the principle of directing secondary air along the sides of the furnace and creating a fuel rich zone in the center of the furnace. With the LNCFS, the excess air can be maintained below 20%. Additionally, the installation reduces ash accumulation on the furnace walls, increasing heat absorption and reducing attemperation requirements. With the LNCFS, each corner of the furnace has a tangential wind box consisting of three coal compartments and four auxiliary air compartments. At full load with all three 593 RB coal pulverizers operating, primary transport air from the pulverizers amounts to 23% of the total combustion air. The capacity of one pulverizer is 26,400 lbs/hr, with 52 grind coal with 70% minus 200 mesh.

Whitewater Valley Unit No. 2 has a Lodge Cottrell cold side precipitator which was erected with the boiler. The precipitator treats 227,000 actual cubic feet per minute of 316°F flue gas with 45,000

Figure 1-1 Project Organization



square feet of collection area (CA). Total CA of the ESP is 198 square feet/1,000 ACFM. The unit has two mechanical fields and four electrical fields and achieves 98.4% removal efficiency (from 3.9 gr/ft^3 to 0.06 gr/ft^3). The ESP performance was optimized by Lodge Cottrell when RP&L purchased new controls in 1985.

Whitewater Valley Unit No. 2's overall efficiency of 87.4% at full load has shown little variation over the years. The unit's average heat rate is 10,280 Btu/kWh. At 60% of full load, the unit's efficiency increases to 88.17%. The unit uses approximately 0.935 pounds of coal per kWh and generates 8.51 pounds of steam per kWh.

The primary emissions monitored at the station are SO_2 and opacity. SO_2 emissions are calculated based on the coal analysis and are limited to 6 lbs/10^6 Btu. Opacity is monitored using an in-situ meter located in the stack and is currently limited to 40%. Current SO_2 emissions for the unit are approximately 4 lbs/10^6 BTU, while opacity at full load ranges from 15 to 30%. Opacity at low load (40-MW) ranges from 3 to 5%. Limited testing was conducted in November 1986 for NO_x emissions. Results from the test work indicated that NO_x emissions averaged 0.65 lbs/10^6 BTU.

Whitewater Valley Unit No. 2 has several important qualities as a LIFAC demonstration site. One of these is that Whitewater Valley Unit No. 2 was the site of a prior demonstration of LIMB sorbent injection technology, jointly sponsored by EPRI and the U.S. Environmental Protection Agency (USEPA). Much of the sorbent injection equipment remained on-site and was used in the LIFAC demonstration. Another advantage of the site is that Whitewater Valley Unit No. 2 was a challenging candidate for a retrofit due to the cramped conditions at the site. The plant is, thus, typical of many U.S. power plants which are potential sites for application of LIFAC. In addition, the Whitewater Valley Unit No. 2 boiler is small relative to its capacity; hence, has a higher temperature profile relative to other boilers. This situation requires sorbent injection at higher points in the furnace to minimize deadburning of the reagent, but it decreases residence times needed for sulfur removal. The demonstration project was intended to show LIFAC's performance under operating conditions typical of U.S. power plants. The project demonstrated LIFAC on high-sulfur U.S. coals and was a logical extension of the Finnish demonstration work which is important for LIFAC's commercial success in the U.S.

1.2.4 Project Schedule

To demonstrate the technical viability of the LIFAC process to economically reduce sulfur emissions from the Whitewater Valley Unit No. 2, LIFAC NA conducted a three-phase project, as follows:

- **Phase I:** **Design**
- **Phase IIA:** **Long Lead Procurement**
- **Phase IIB:** **Construction**
- **Phase III:** **Operations**

Except for Phase IIA, each phase was comprised of three tasks: a management and administration task, a technical task, and an environmental task. The design phase began on August 8, 1990, and was scheduled to last six (6) months. Phase IIA, long lead procurement, overlaps the design phase and was expected to require about four (4) months to complete. The construction phase was to continue for another seven (7) months, while the operations phase was scheduled to last about twenty-six (26 months). Figure 1-2 shows the original estimated project schedule which is based on an August 8, 1990, start date and a planned outage of Whitewater Valley Unit No. 2 during March 1991.

It was during this outage that all the tie-ins and modifications to existing Unit No. 2 equipment were made. This required that the construction phase begin in early February 1991 -- construction was to be completed by the end of August 1991. Operations and testing were to begin September 1991, and continue for 26 months. However, the project encountered delays in receiving its construction permit. These delays, along with some design changes and an approved expansion in project scope, required that the Design Phase be extended by about eleven months. Therefore, construction was not completed until early June 1992. This represented an eight-month extension in the overall schedule.

During the last half of 1992, problems were encountered during startup and commissioning of some of the LIFAC components and systems. These problems required the parametric tests to be delayed until the first quarter 1993, which subsequently required adjustments in the entire testing schedule. During the initial parametric tests, problems were encountered with increased opacity levels. These problems forced an extension in the parametric test schedule, and, consequently, an adjustment was made to the testing schedule as shown in Figure 1-3. These delays, however, did not impact the

Figure 1-2

LIFAC Demonstration

Original Project Schedule

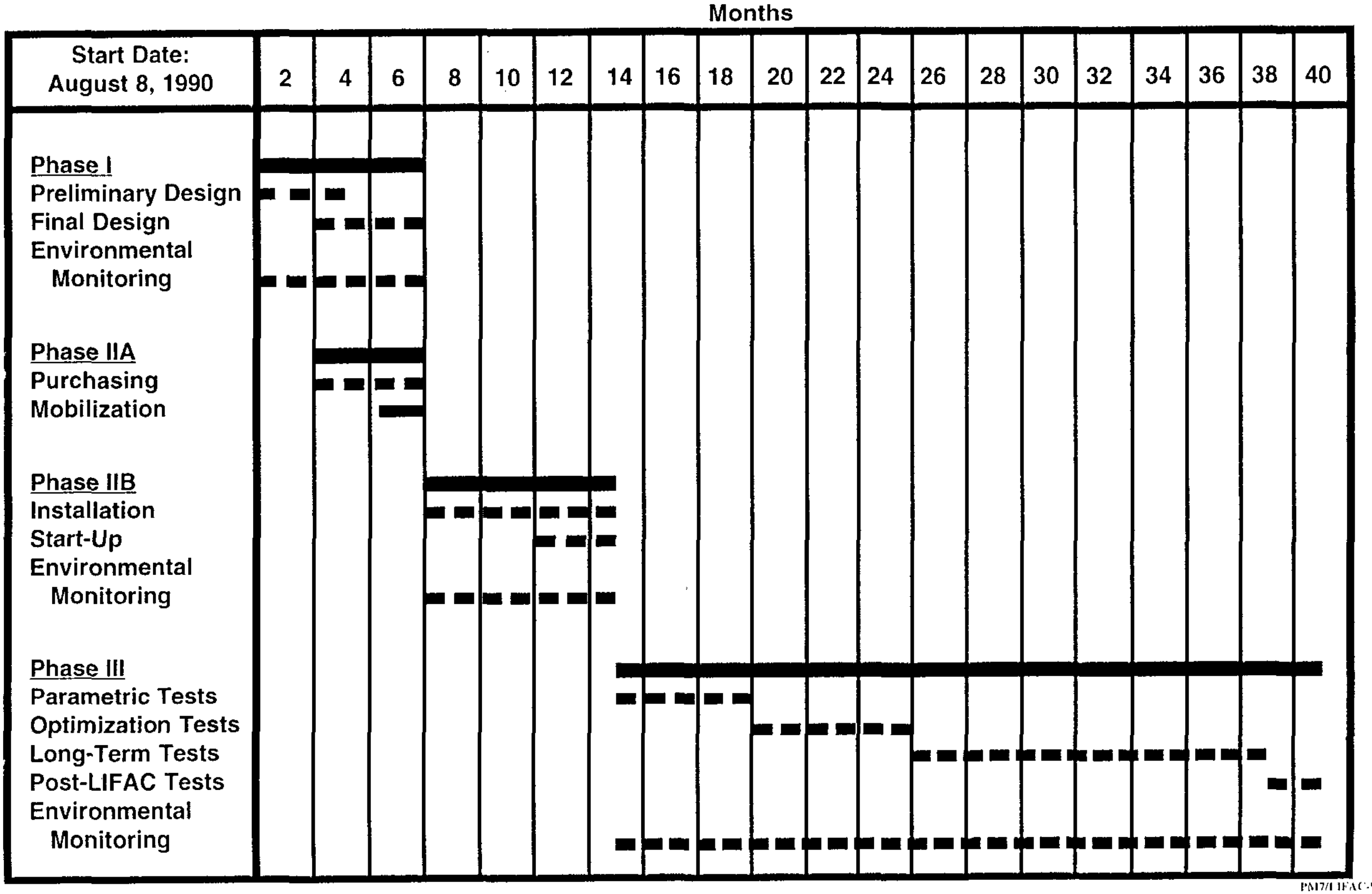
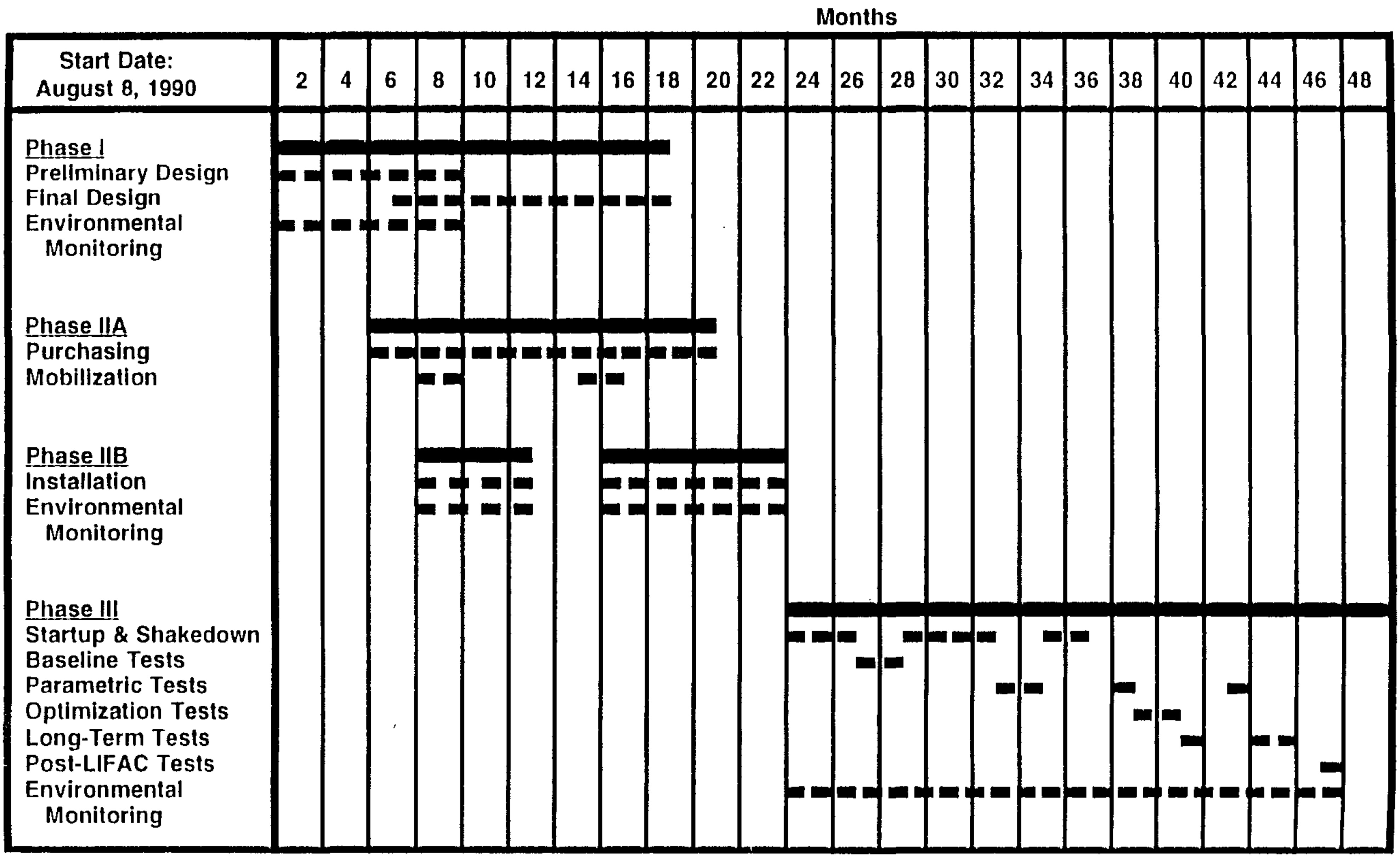


Figure 1-3

LIFAC Demonstration

Current Project Schedule

(Revised June 1993)



overall duration of the Phase III activities and the total project duration remained at the modified 48 months.

1.2.5 Test Plan

The test program had five sets of tests: baseline testing, parametric testing, optimization testing, long-term testing, and post-LIFAC testing. The baseline tests were designed to establish a set of current conditions at which the host's system operates and served as the basis of comparison for all other tests. The parametric tests consisted of determining the optimum settings of a wide range of process parameters. The parametric tests also tested the efficiency of different limestones as sorbents. The optimization tests were for the purpose of "fine-tuning" before the long-term tests. The aim of the optimization tests was to evaluate operability of the process in optimum process settings determined during the parametric tests. The long-term tests were long-duration tests. During these tests, the efficiency and economics of the process were to be evaluated with different coals. After the long-term tests, the baseline tests were repeated as post-LIFAC tests. A block diagram of the test program is shown below in Figure 1-4.

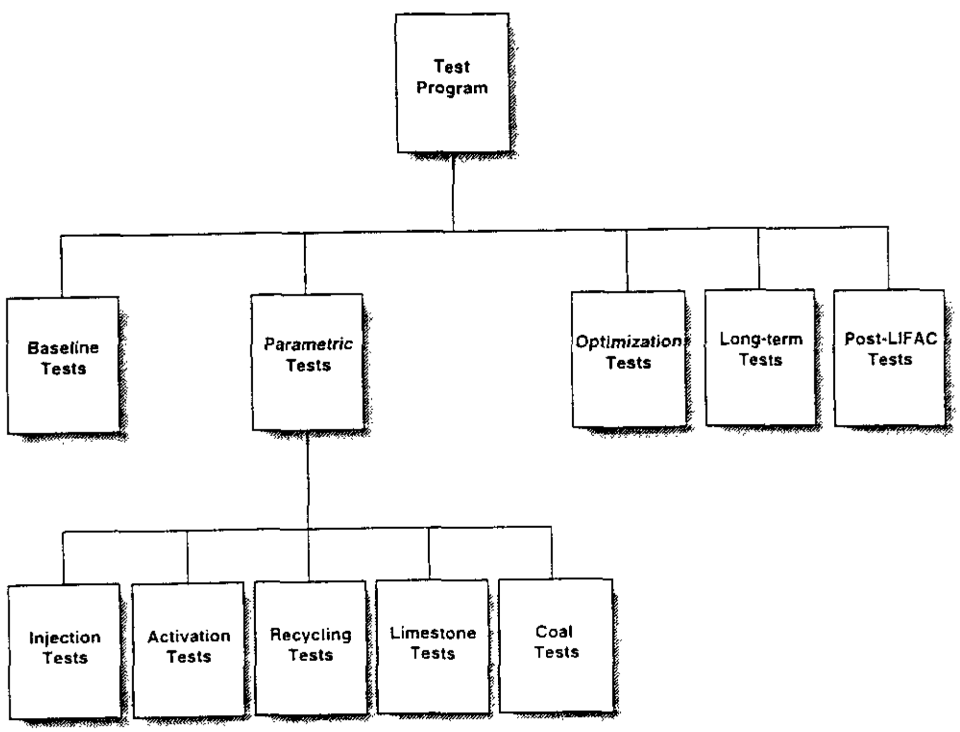


Figure 1-4

Structure of the LIFAC Desulfurization Process Test Program

1.3 Project Objectives

The sponsors of this project believe that LIFAC has the potential to be a new and important SO_2 control option for U.S. utilities subject to the Clean Air Act's acid rain regulations. To be considered as a commercially feasible option in this particular emission control market, LIFAC must demonstrate a high SO_2 removal rate while remaining competitive with other options on a cost per ton of SO_2 removed basis. To this end, the sponsors of this project designed the demonstration with the following objectives in mind:

- Sustained High SO_2 Removal Rate - Incorporated into the test plan were several periods of long-term testing which were intended to demonstrate LIFAC's SO_2 removal and reliability characteristics under normal operating conditions.

- Cost - LIFAC must compete with both low capital cost, low SO_2 removal rate options such as sorbent injection, and high capital cost, high SO_2 removal rate options such as wet scrubbing. This project was designed to demonstrate LIFAC's competitiveness on a cost per ton of SO_2 removed basis with currently available alternatives.

- Retrofit Adaptability - The host site chosen required a retrofit with tight construction conditions that would prove LIFAC's ability to be installed where other technologies might not be possible. Construction was intended to also demonstrate LIFAC's ability to be built and brought on-line with zero plant downtime other than scheduled outages.

- System Compatibility - A major concern of utilities is the degree of compatibility of SO_2 removal systems with their existing operations. This demonstration showed LIFAC's minimal impact on the host site's boiler and associated subsystems.

1.4 Significance of the Project Commercialization and Process Advantages

The significance of this project was to show that the LIFAC technology could provide SO_2 removal at a significant rate and competitive costs, while utilizing U.S. coals. A successful demonstration would provide another option for power plants besides costly wet scrubbers, with minimal impacts to the host site.

Wet scrubbers are the most prevalent FGD technology and account for approximately 90% of U.S. scrubber systems. Wet FGD systems that use lime or limestone remove about 90% of the SO_2 and usually produce a sulfite/sulfate sludge waste product. Although the LIFAC process cannot match the high removal rates (90% or more) achieved by conventional wet scrubbers, the process does offer several advantages including:

- The technology can be more easily retrofit onto most small power plants (100-150 MW). The vertical activation chamber requires less space. However, with larger boilers (450-500 MW) several LIFAC systems would be required at which point wet scrubbers are more feasible.

- The technology has lower capital costs which makes it especially attractive to existing plants that have fewer years to amortize capital investments as compared to long-lived power plants.

- The technology uses a widely available reagent, limestone, rather than more expensive sorbent materials, such as lime.

- The need for slurry preparation/handling equipment is eliminated.

- The waste product is dry and easy to handle. In comparison, conventional wet limestone scrubbers produce a wet sludge which requires special handling and treatment.

- The technology is typically compatible with other plant systems such as electrostatic precipitators (ESPs) and induced draft (ID) fans, thereby minimizing costly retrofit plant modifications in order to employ the technology.

The LIFAC system also has potential advantages over less conventional sorbent injection systems now being tested. These include:

- Use of limestone as opposed to lime or other more expensive sorbents.

- Removal rates of 75-85%, which exceed the removal rates of many dry sorbent injection systems.

- Improved control of wall deposition and fouling associated with humidification in vertical chamber as opposed to in-duct humidification.

The LIFAC technology's potential for commercialization is increased by its ability to remove 75-85% of the SO_2, its low space requirement, and its low retrofit costs.

1.5 DOE's Role in the Project

The DOE was responsible for monitoring all aspects of the project and for granting or denying all approvals required by the Cooperative Agreement. The DOE Contracting Officer is DOE's authorized representative for all matters related to the Cooperative Agreement.

The DOE Contracting Officer appointed a Contracting Officer's Technical Representative (COTR) who is the authorized representative for all technical matters and has the authority to issue "Technical Advice" which may:

- Suggest redirection of the cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, and suggest pursuit of certain lines of inquiry which assist in accomplishing the Statement of Work.

- Approve those reports, plans, and items of technical information required to be delivered by the Participant to DOE under the Cooperative Agreement.

The DOE COTR does not have the authority to issue any technical advice which:

- Constitutes an assignment of additional work outside the Statement of Work.

- In any manner causes an increase or decrease in the total estimated cost or the time required for performance of the Cooperative Agreement.

- Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

2.0 TECHNOLOGY DESCRIPTION

2.1 Chemical Process

The LIFAC (Limestone Injected into the Furnace with Activation of untreated Calcium oxide) technology combines upper-furnace limestone injection followed by post-furnace humidification in an activation reactor located between the air preheater and the ESP. The process produces a dry and stable by-product that is partially removed from the bottom of the activation reactor and partially removed at the ESP.

Finely pulverized limestone (80% < 325 mesh) is pneumatically conveyed and injected into the upper part of the furnace. Since the temperatures at the point of injection are in the range of 1800 - 2000 ° F, the limestone ($CaCO_3$) thermally decomposes to form calcium oxide (CaO). As the CaO passes through the furnace, initial desulfurization reactions occur. A portion of the sulfur dioxide (SO_2) reacts with the CaO to form calcium sulfite ($CaSO_3$) which oxidizes to calcium sulfate ($CaSO_4$). Essentially all of the sulfur trioxide (SO_3) reacts with CaO to form $CaSO_4$.

The flue gas, unreacted CaO, and ash exit the boiler and pass through the air preheater. On leaving the air preheater, the gas/CaO/ash mixture is directed to the LIFAC activation reactor. In the reactor, additional SO_2 capture occurs after the flue gas is humidified with a water spray. Humidification converts CaO to calcium hydroxide, $Ca(OH)_2$, which enhances further SO_2 removal. The primary reaction product in the activation reactor is calcium sulfite ($CaSO_3$). The activation reactor is designed to allow time for effective humidification of the flue gas, activation of the CaO, and reaction of SO_2 with the sorbent. All the water droplets evaporate before the flue gas leaves the activation reactor. The net effect is that at a Ca/S molar ratio in the range of 2:1 to 2.5:1, 75-85% of the SO_2 is removed from the flue gas.

The flue gas leaving the activation reactor enters the existing ESP, where the spent sorbent and fly ash are removed from the flue gas and sent to the disposal facilities. The solids collected by the ESP consist of fly ash, $CaCO_3$, CaO, $Ca(OH)_2$, $CaSO_4$, and $CaSO_3$. To improve utilization of the calcium and increase SO_2 removal, a portion of the spent sorbent collected in the ESP hoppers is recycled to the ductwork just ahead of the activation reactor.

Figure 2-1 is a simple flow diagram of the LIFAC process as designed at the RP&L host site. The major process areas are as follows:

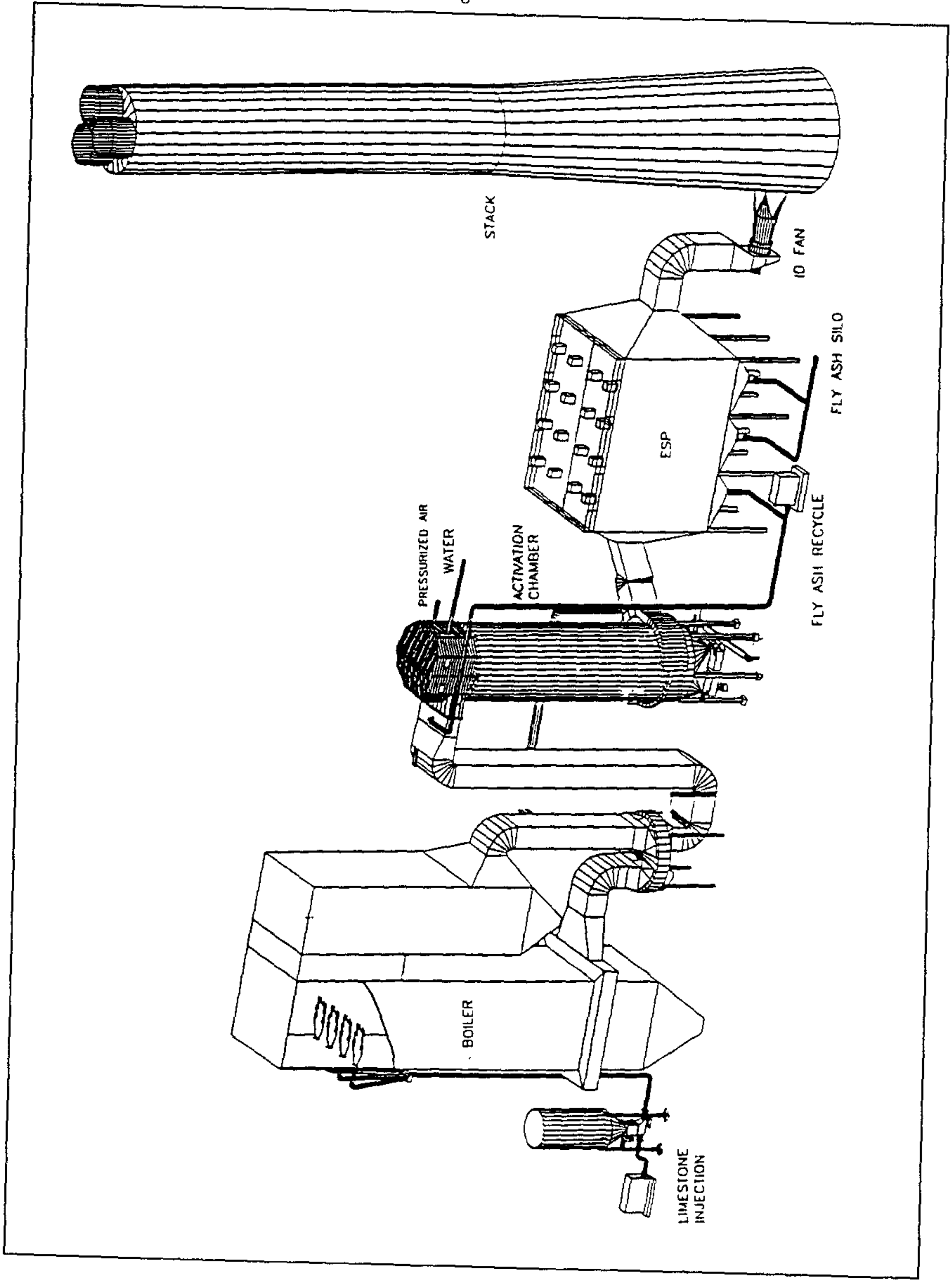
- Limestone Storage and Handling Area
- Boiler Injection Area
- Activation Reactor Area
- ESP Ash Recycle Area
- Process Monitoring and Control

(These areas are discussed in detail in Section 3.2.)

Note that proprietary information within the reactor consists of the following:

- Specific residence time
- Water droplet sizes
- Distribution mechanism

Figure 2-1 LIFAC Overall Block Flow Diagram



3.0 PROCESS DESIGN CRITERIA

The calculated design values for LIFAC are based on certain assumptions regarding Whitewater Valley Unit No. 2, the typical coal burned at the facility, and the predicted sorbent quality. Ultimate and proximate analyses of the reference coal were completed during the design phase. Table 3A below shows the coal analysis and other assumptions which were used in the preliminary design calculations. Copies of the coal analysis are provided in Appendix I. The flow values presented in the following subsection are based on the values shown in Table 3A.

COAL ANALYSIS:	
Higher Heating Value	**11178 Btu/lb**
Carbon	**62%**
Sulfur	**2.4%**
Oxygen	**7%**
Nitrogen	**1.2%**
Hydrogen	**4.4%**
Ash	**10%**
Moisture	**13%**
TOTAL	**100%**

DESIGN BASIS:	
Generating Efficiency	**33%**
Excess Air Factor	**1.304**
Air Preheater Leakage	**7%**
Humidification Rate	**80%**
Ca/S Molar Ratio	**2.00**
Limestone Purity (% $CaCO_3$)	**90%**
Furnace Bottom Ash	**15% without LIFAC** **10% with LIFAC***
Air Preheater Ash	**5%**

*Same quantity with or without LIFAC accounts for limestone injection and assumes 100% ash removal.

Table 3A Process Values Used for Preliminary Design Calculations

3.1 Process Flow Diagram

A process flow diagram was developed for the LIFAC desulfurization process. In Table 3B, thirty-three process streams are identified, showing flow rates, pressures, and temperatures at both high (65 MW) and low (40 MW) boiler loads. Figure 3-3 is a flow diagram of LIFAC as it was installed at RP&L. The figure provides the physical locations of all the process streams referred to in the tables. Table 3C displays the maximum, or worst case, process values which were used as an upper limit for the range of design values.

3.2 Process Areas

The nature and physical layout of the host site, combined with its history as the location of a previous demonstration project, helped to define some of this project's design criteria. In 1989, RP&L served as the host site for the demonstration of a lime injection system under the acronym of LIMB. Much of the equipment installed for that project remained on-site, and its reuse for LIFAC was considered where possible. In addition, RP&L's Unit No. 2 boiler is small, with tight surrounding clearances which had to be accounted for in the design of the LIFAC boilerhouse equipment and installation procedures. Also included in the design criteria was the need to install all the necessary tie-ins to plant systems during Unit No. 2's short downtime periods. The remaining construction period for LIFAC could not interfere with normal daily plant operations.

The LIFAC system at RP&L can be divided into the following five design areas:

- Limestone Storage and Handling Area
- Boiler Injection Area
- Activation Reactor Area
- ESP Ash Recycle Area
- Process Monitoring and Control

3.2.1 Limestone Storage and Handling Area

The majority of the equipment remaining from the previous lime injection demonstration was used for handling and storage of the hydrated lime. Figure 3-5 is a mechanical arrangement (plan) drawing of the limestone storage and handling area. Existing equipment is shown using dashed lines. Because

TABLE 3B

NORMAL LIFAC FLOW VALUES AT HIGH AND LOW BOILER LOADS (Refer to Figure 3-3 for Location of Components)

No.	Component	65MW			40 MW		
		Flow	Pressure	Temperature	Flow	Pressure	Temperature
1	Sorbent	404 lbs/min	--	70 F	404 lbs/min	--	70 F
2	Sorbent	400 lbs/min	--	70 F	400 lbs/min	--	70 F
3	Sorbent	200 lbs/min	--	70 F	123 lbs/min	--	70 F
4	Injection Air	759 acfm	11.6 psig	175 F	759 acfm	11.6 psig	175 F
5	Secondary Air	4269 acfm	1.73 psig	95 F	4269 acfm	1.73 psig	95 F
6	Total Sorbent Air	6034 acfm	0 psig	100 F	6034 acfm	0 psig	100 F
7	Coal	336 lbs/min	--	70 F	206 lbs/min	--	70 F
8	Coal	336 lbs/min	--	70 F	206 lbs/min	--	70 F
9	Coal	336 lbs/min	--	70 F	206 lbs/min	--	70 F
10	Sorbent Air	521 acfm	7.25 psig	145 F	521 acfm	7.25 psig	145 F
11	Turbine Steam	9000 lbs/min	1320 psig	955 F	5400 lbs/min	1275 psig	955 F
12	Bottom Ash	28 lbs/min	--	--	17 lbs/min	--	--
13	Flue Gas after Econ.	336700 acfm	-4.7 " H_2O	665 F	192800 acfm	-1.7 " H_2O	577 F
14	Fly Ash after Econ.	251 lbs/min	--	665 F	154 lbs/min	--	577 F
15	Preheater Ash	14 lbs/min	--	--	9 lbs/min	--	--
16	Preheated Air	228043 acfm	10.6 " H_2O	530 F	130990 acfm	10.6 " H_2O	471 F
17	Flue Gas	263600 acfm	-12.6 " H_2O	347 F	152000 acfm	-4.3 " H_2O	299 F
18	Fly Ash	237 lbs/min	--	347 F	145 lbs/min	--	299 F
19	Flue Gas after Reheat	228800 acfm	-16.7 " H_2O	167 F	138100 acfm	-5.8 " H_2O	167 F
20	Fly Ash after Reheat	427 lbs/min	--	167 F	262 lbs/min	--	167 F
21	Nozzle Air	326 acfm	80 psig	104 F	337 acfm	80 psig	104 F
22	Nozzle Water	103 gpm	48 psig	50 F	49 gpm	28 psig	50 F
23	Vibrator Air	70 acfm	101.5 psig	104 F	70 acfm	101.5 psig	104 F
24	Dumpster/Truck Slag	58 lbs/min	--	122 F	35 lbs/min	--	122 F
25	Flue Gas	221500 acfm	-15.3 " H_2O	149 F	134000 acfm	-5.2 " H_2O	149 F
26	Fly Ash	427 lbs/min	--	149 F	262 lbs/min	--	149 F
27	Reheat Steam	103 lbs/min	244 psig	570 F	65 lbs/min	244 psig	570 F
28	Condensate Water	12.3 gpm	101.5 psig	325 F	7.8 gpm	101.5 psig	325 F
29	Recirc. Fly Ash	248 lbs/min	--	122 F	152 lbs/min	--	122 F
30	ESP Transport Air	681 acfm	70 psig	140 F	681 acfm	7.0 psig	140 F
31	System Fly Ash	178 lbs/min	--	167 F	108 lbs/min	--	167 F
32	Particulate Matter	1.7 lbs/min	--	158 F	10 lbs/min	--	158 F
33	Flue Gas	228100 acfm	-21 " H_2O	158 F	136500 acfm	-6.8 " H_2O	158 F

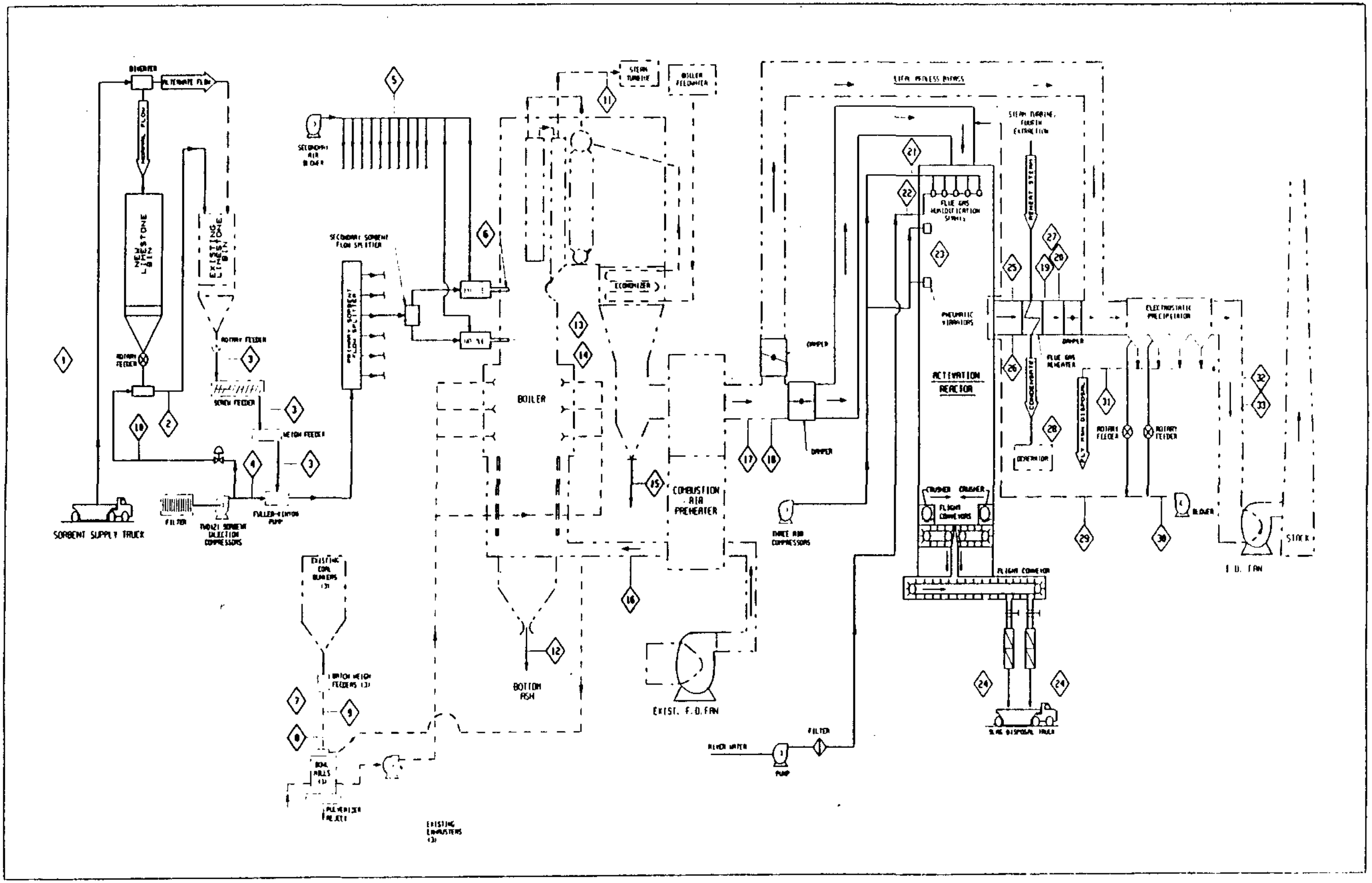


Figure 3–3 LIFAC Desulfurization Process Flow Diagram

TABLE 3C

MAXIMUM LIFAC FLOW VALUES AT 65 MW
(Refer to Figure 3-3 for Location of Components)

No.	Component	65MW		
		Flow	Pressure	Temperature
1	Sorbent	417 lbs/min	--	70 F
2	Sorbent	400 lbs/min	--	70 F
3	Sorbent	300 lbs/min	--	70 F
4	Injection Air	759 acfm	11.6 psig	175 F
5	Secondary Air	6237 acfm	1.73 psig	95 F
6	Total Sorbent Air	8448 acfm	--	100 F
7	Coal	336 lbs/min	--	70 F
8	Coal	336 lbs/min	--	70 F
9	Coal	336 lbs/min	--	70 F
10	Sorbent Air	521 acfm	7.25 psig	145 F
11	Turbine Steam	9000 lbs/min	1320 psig	955 F
12	Bottom Ash	37 lbs/min	--	--
13	Flue Gas after Econ.	360200 acfm	-4.7 " H_2O	665 F
14	Fly Ash after Econ.	330 lbs/min	--	665 F
15	Preheater Ash	18 lbs/min	--	--
16	Preheated Air	228043 acfm	10.6 " H_2O	530 F
17	Flue Gas	282100 acfm	-12.6 " H_2O	347 F
18	Fly Ash	312 lbs/min	--	347 F
19	Flue Gas after Reheat	247000 acfm	-16.7 " H_2O	167 F
20	Fly Ash after Reheat	562 lbs/min	--	167 F
21	Nozzle Air	337 acfm	101.5 psig	104 F
22	Nozzle Water	115 gpm	64 psig	50 F
23	Vibrator Air	70 acfm	101.5 psig	104 F
24	Dumpster/Truck Slag	1467 lbs/min	--	122 F
25	Flue Gas	239100 acfm	-15.3 " H_2O	149 F
26	Fly Ash	562 lbs/min	--	149 F
27	Reheat Steam	112 lbs/min	244 psig	570 F
28	Condensate Water	13.4 gpm	101.5 psig	325 F
29	Recirc. Fly Ash	324 lbs/min	--	122 F
30	ESP Transport Air	681 acfm	7.0 psig	140 F
31	System Fly Ash	310 lbs/min	--	167 F
32	Particulate Matter	2.2 lbs/min	--	158 F
33	Flue Gas	246200 acfm	-27 " H_2O	158 F

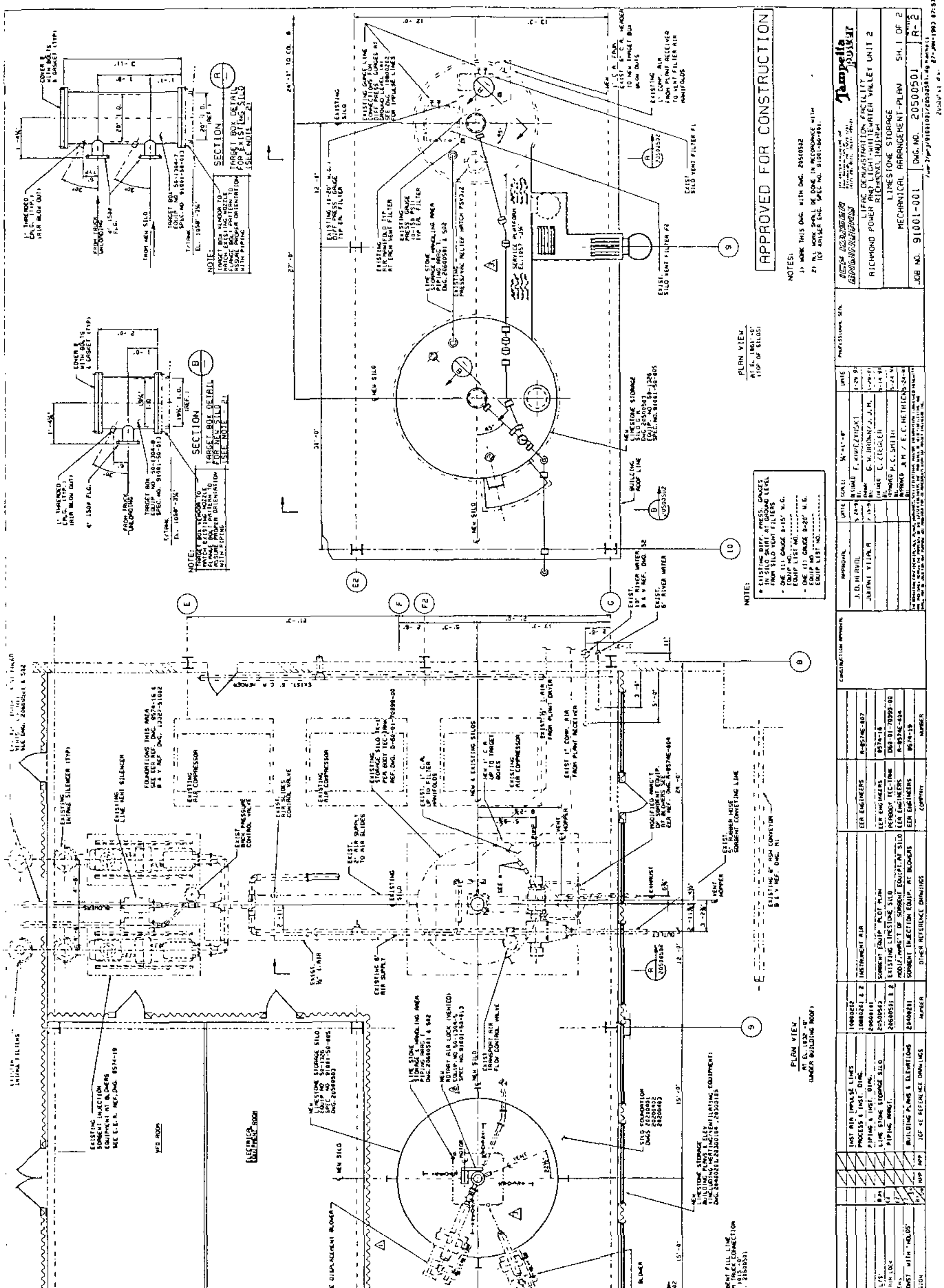


Figure 3-5 Limestone Storage and Handling Area

of the similarities between the physical characteristics of limestone and hydrated lime, the utilization of this equipment was a high priority in designing the limestone system. Inspection of this equipment allowed reuse of the following items:

- 125 ton Storage Silo (now a LIFAC feed silo)
- Limestone Feeding System
- Two Vent Baghouses

The LIFAC system was designed for operation on a continuous basis at a limestone injection rate of 200 lb/min, which necessitated the inclusion of additional limestone storage and handling equipment. A new 250 ton storage silo was designed to provide enough storage capacity for LIFAC to operate three days, such as over a weekend, without any limestone deliveries.

The pulverized limestone arrives at the plant via truck transport. A pneumatic transport line which can serve either the new or existing silo was designed with a maximum operating pressure of 16 psi and flow rate of 17 lb/min. The transport line has replaceable wear back fittings on all elbows along with Victaulic couplings. A manual diverter valve on the roof of the new silo directs the limestone to either of the two silos.

Limestone is transported pneumatically from the new storage silo to the existing silo for injection into the boiler. The new silo has air slides which fluidize the limestone and ensure an even, continuous flow of material by gravity to a rotary valve. The rotary valve feeds a conveying tee where transport air is introduced to carry the limestone to the top of the existing silo. The capacity of the transport pipe is 400 lb/min of limestone. The transport air is supplied by a new rotary lobe air blower with a maximum capacity of 1600 ACFM at 12 psig.

Limestone quantity in the silos is determined by measuring the weight of the silos with weight cells. Both the new and existing silo have a set of level indicators. The new silo has been equipped with low, high and high/high indicators, while the existing silo has only low and high levels indicators from the previous demonstration. On the top of the existing silo there are two vent baghouses to prevent dust emissions from the silos during truck unloading. The new storage silo has a pressure equalizing vent to the existing silo. Both silos have manually-operated knife gate valves above their rotary valves. The gate valve on the existing silo is used to isolate the silo material from the weigh feeding equipment.

Limestone injection into the host boiler may be performed only from the existing feed silo. The LIMB demonstration left behind the following equipment which was utilized in the LIFAC design:

- Gravimetric Weigh Feeder and Control System
- Fuller-Kinyon Pump
- Rotary Valve
- Flexible Lime Transport Pipe to Boiler
- Flow Control and Pressure Relief Valve

Limestone from the existing feed silo is fed by the rotary valve to the weigh feeder. The rotary valve is equipped with a variable speed DC-drive which receives an input control signal from the weigh feeder system's controller. The weigh feed consists of a feeder screw and a weigh screw. The feeder screw operates at a constant speed and transports the limestone evenly to the weigh screw. The weigh screw is mounted on load cells and the mass flow rate of limestone is determined by multiplying the weight of material on the screw by its rotation rate.

The limestone is dropped by the weigh screw feeder into the Fuller-Kinyon pump for transport to the boiler. The Fuller-Kinyon pump has a screw which feeds the limestone to a chamber where transport air from the new blower is introduced for pneumatic transport. The maximum design feed rate is 300 lb/min of limestone at 12 psig. The Fuller-Kinyon pump is equipped with an existing vent baghouse and it also serves as an airlock, using the material and check valve to isolate the transport line from the silo. Attached to the pump is a section of flexible hose 8 inches in diameter, which is used to pneumatically convey the pulverized limestone into the boilerhouse and connects to steel piping with replaceable elbows.

3.2.2 Boiler Injection Area

Because of higher limestone flow rates and the large number of injection ports on the boiler, no boiler injection equipment from the LIMB demonstration could be utilized. A new primary splitter was designed which separates the incoming limestone from the Fuller-Kinyon pump into six streams. The primary splitter is equipped with two blowout connections for each of the six streams to clean any plugged material. Each of these six streams has another secondary splitter to achieve the needed twelve streams for every injection location on the boiler. Figure 3-6 shows a plan view of the secondary splitter and boiler injection hoses.

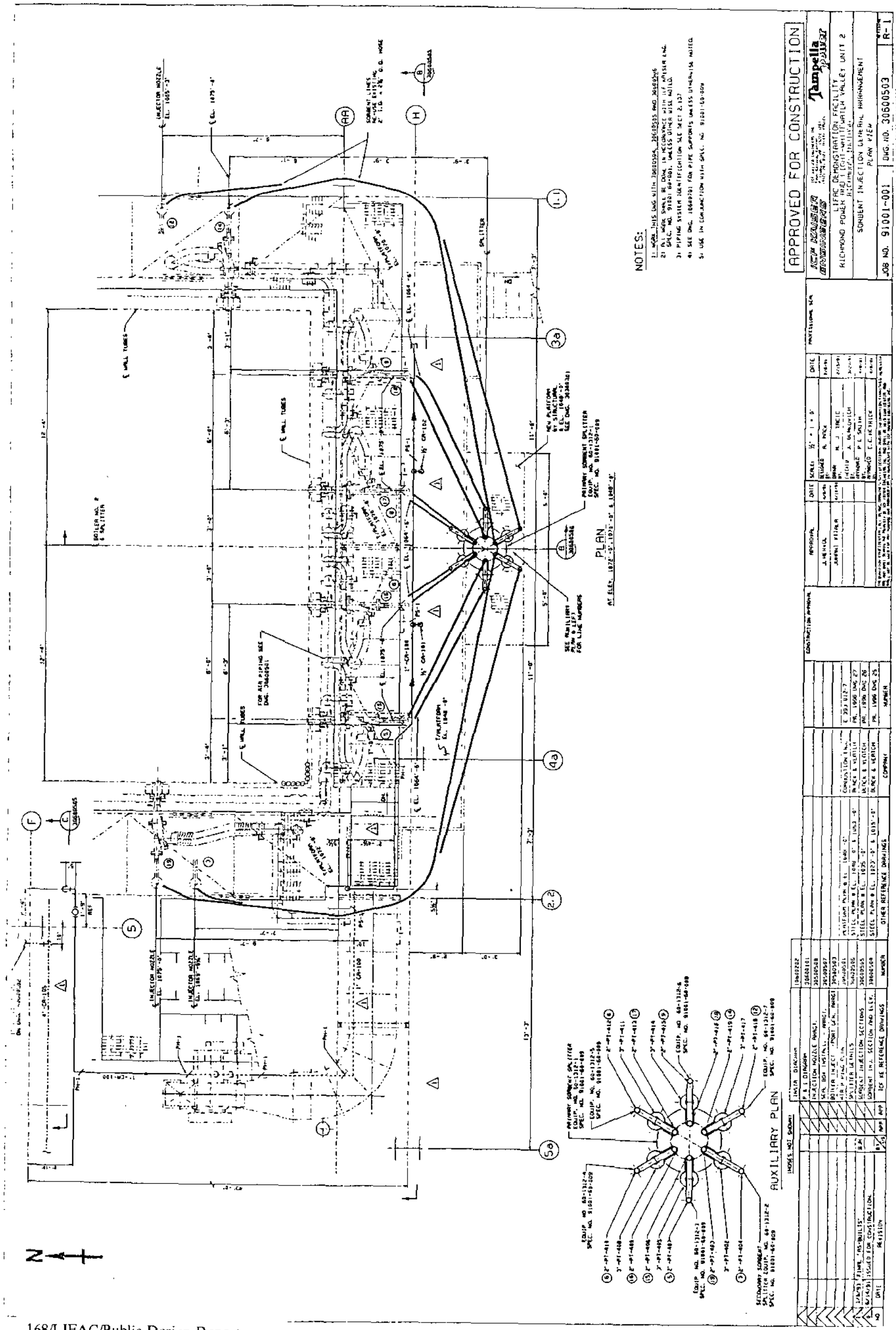


Figure 3-6 Boiler Injection Area

The limestone is moved from the secondary splitters to the boiler injection nozzles via a carbon steel pipe with flexible hose ends to allow for boiler expansion and contraction. There are six injection nozzles on two different levels of the boiler. Each level has four injection ports on the south boiler wall and one on both the east and west walls. Boiler injection port locations are shown in Figure 3-6a. These ports may be used in any combination to allow optimum SO_2 removal at different boiler loads.

The injection nozzles are made of stainless steel and include a sight glass to check for limestone pluggage. Mounted to the boilerhouse structural steel, these nozzles may be adjusted vertically to accommodate boiler expansion. The nozzles can also pivot ± 15° to achieve a range of injection angles into the boiler.

A secondary air fan has been provided at the injection location to ensure that the velocity needed for deep penetration and even dispersal of the limestone into the boiler is achieved. This constant speed fan is equipped with a remotely-controlled variable position damper and moves a maximum of 6,700 SCFM of air at 1.73 psig. The air is carried by ductwork to the south boiler wall, where 12 sections of flexible tubing are connected to each injection nozzle. Each section of flex tubing contains one manually-controlled fixed position damper and a second flow controlled damper. The mixing of the secondary air and limestone in the injection nozzle may be viewed through the sight glass.

3.2.3 Activation Reactor Area

The reactor area includes all the ductwork, the reactor vessel itself, and the associated systems that handle and humidify the flue gas after the boiler and before it enters the ESP. This proprietary aspect of the process is unique to the LIFAC process; and, therefore, the only equipment that could be reused were three Ingersoll Rand compressors for atomizing air supply.

The reactor vessel, as shown in Figure 3-7, is a vertical chamber in the ductwork where humidification of the flue gas occurs. The vessel is 133 ft. high and 28 ft. in diameter. It is designed with 3/8-inch thick stainless steel walls to prevent corrosion caused by the precipitation of acid in the humidified flue gas. The vessel has a maximum design pressure of negative 25 inches of water and a temperature of 400°F. Also included in its design are base slide plates and walkways, with one fixed and one free

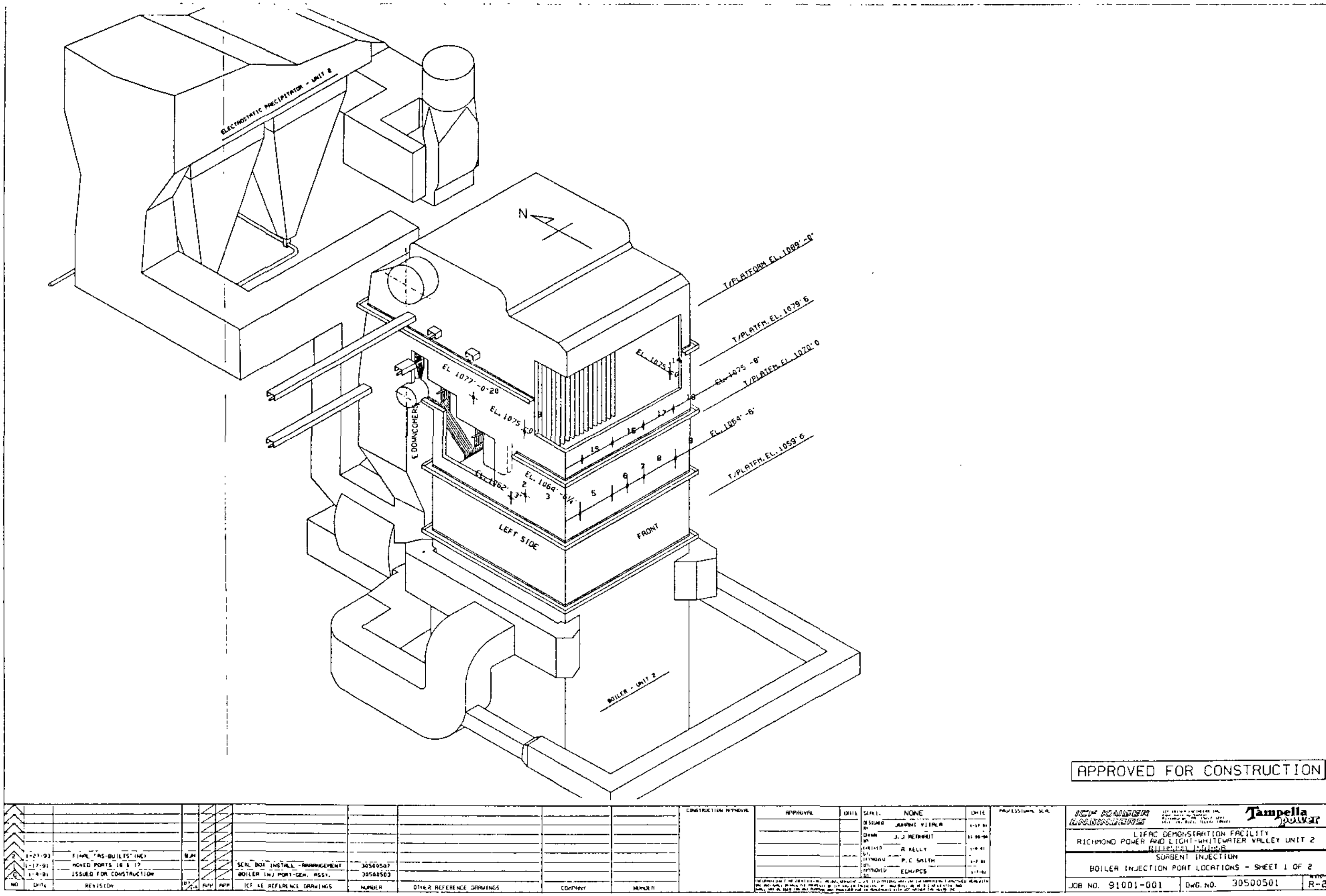


Figure 3-6a Boiler Injection Port Locations

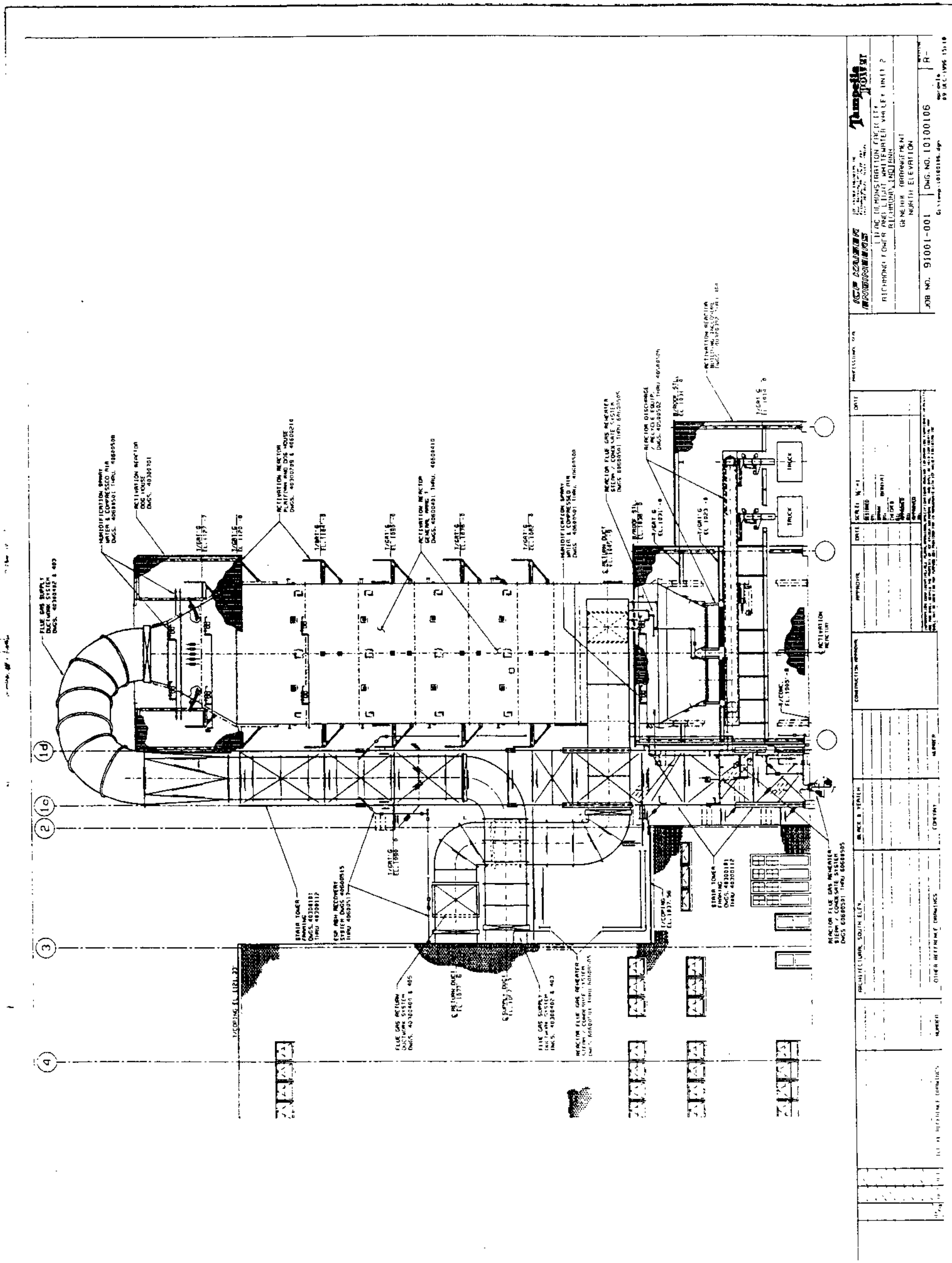


Figure 3-7 LIFAC Activation Reactor

end to allow for maximum thermal growths of 4.5 inches vertical and 1 inch horizontal. There are also five levels of inspection doors, with six doors on each level, to permit access to the interior of the vessel for visual inspection, flue gas measurements, and repair work.

The bottom section of the reactor vessel interior contains a baffle cone which reduces the cross-sectional area and redirects the flue gas flow 180 degrees upward. This allows some of the ash to fall out of the gas stream for collection. At the top outside portion of the baffle cone are three equally spaced outlet duct openings for the exiting flue gas.

Instrumentation on the reactor vessel consists of thermocouples and differential pressure indicators. These instruments create a temperature profile and measure the pressure drop across the reactor vessel. Temperature readings determine the amount of reheat steam necessary to keep the flue gas safely above its saturation temperature.

Flue gas from the boiler is carried to the reactor vessel via a section of bypass ductwork that is tied to the host site's ductwork immediately following the air preheater. The ductwork has been sized according to a maximum gas flow rate of 282,100 ACFM with the Unit No. 2 load at 65 MW. Thermal expansion is compensated for by three expansion joints from 9 to 18 inches in width. Sliding base plates are also employed for lateral ductwork movement. The return ductwork is similar, although there are three outlet openings from the reactor vessel, each having its own expansion joint. The remaining ductwork has six expansion joints, each 12 inches in width. The design of the ductwork includes both turning vanes in the bends to reduce turbulence in the gas flow and 6 inches of insulation to reduce heat loss.

Installed in the three outlet duct legs leaving the reactor are three stainless steel steam reheaters. These reheaters raise the outlet flue gas temperature enough to prevent acid precipitation in the Lodge Cottrell ESP units. The steam supply for the reheaters is from the plant's medium pressure steam system which is at 570°F and 246 psi. The maximum combined throughput of the three units at these operating conditions is 9000 lb/hr of steam. A steam-driven condensate collection system returns the condensate to the plant's system.

In both the inlet and outlet sections of ductwork to the reactor vessel are located a pair of analyzers that take SO_2, NO, and O_2 readings, thereby measuring the effectiveness of the reactor vessel in reducing emissions. Three flow elements measure the actual amount of flue gas being treated by the reactor, while three differential pressure indicators measure the flow exiting the reactor.

The humidification system requires water and a compressed air supply. Water is provided by a ground level centrifugal pump with maximum operating specifications of 115 GPM and 175 psig. The water supply may come from the plant's river water supply or its chilled water system. A duplex basket-type strainer, installed immediately after the pump, removes any large particulates. The water is then pumped vertically approximately 135 feet to the top of the reactor.

Three Ingersoll Rand helical screw air compressors provide the atomizing air for the humidification. Each compressor has a capacity of 870 ACFM at 125 psig and is located in the limestone storage area. At the top of the reactor in the penthouse, the air and water are combined in dual fluid nozzles. The air distributes the water evenly into the flue gas inside the top of the reactor. Each of the clusters of fluid nozzles has an air-operated scraper to remove ash deposits. The compressors supply the air for the scrapers as well as two sets of vibrators which prevent the buildup of ash on the inside of the reactor vessel.

Instrumentation on the water supply consist of an orifice plate to measure flow and a flow control valve. The flow rate of the water is determined by the temperature of the flue gas leaving the reactor vessel. The air line has a pressure control valve which can be set independent of the flue gas temperature.

The ash separated from flue gas in the bottom of the activation reactor is removed with two bottom drag conveyors. Both of these conveyors have a 22 ton/hr capacity and are furnished with crushers for larger accumulations of ash which may be dislodged by the reactor's vibrators. The motors on the drag chain and the crusher are reversible in case of jamming. Ash from the bottom drag conveyors is dropped onto a flight transfer conveyor, moving the ash to a pair of double-dump valves which empty into roll off containers for disposal. The double dump valves provide a constant seal to maintain the negative pressure of the flue gas stream through the reactor.

3.2.4 ESP Recycle Area

The ash separated from flue gas by the Lodge Cottrell ESP units is removed by gravity and pneumatically recycled directly into the flue gas ductwork immediately preceding the reactor.

Figure 3-8 provides a mechanical arrangement of the ESP recovery and recycle system used in the LIFAC process. Two of the four ESP hoppers are equipped with variable speed rotary valves which feed two conveying tees where transport air is introduced. A rotary lobe blower provides a maximum of 890 ACFM of air at 7 psig. A manually operated diverter valve in the transport line determines whether the ash is directly recycled or sent to a 10 ton capacity ash surge tank in the reactor area. The surge bin was designed and installed for future use if needed.

3.2.5 Process Monitoring and Control

The operation of the LIFAC process is controlled by the PLC (programmable logic controller) using ICF Kaiser proprietary process control software. The process control system is used only for the LIFAC equipment. The operation of the boiler equipment and associated subsystems continue to be controlled by the power plant's original control system and is only monitored by LIFAC's software.

The process control system hardware consists of two identically installed IBM 756 Industrial computers with 19" VGA color monitors. Both computers are located in the boiler control room. One unit is used to control the entire LIFAC process. A printer for alarm reporting is connected to this computer. The other computer, the monitoring computer, is intended to monitor and collect data. It can also be used as a spare control computer, if necessary.

All the control commands from the control computer to the equipment and feedback data from the equipment and instruments to the computers are transported through three input/output (I/O) racks. Rack No. 1 is for the boilerhouse equipment and instruments; rack No. 2 is for the limestone area equipment and instruments; and rack No. 3 is for the activation reactor area equipment and instruments. The system has a total of 333 input or output points: 29 RTD's, 51 analog inputs, 35 analog outputs, 160 digital inputs, and 58 digital outputs.

3.3 Host Site Modifications

3.3.1 Boiler

LIFAC boiler modifications were minimal as its design took advantage of the work performed under the LIMB demonstration project. Twelve injection ports into the boiler were required for the limestone system, with seven ports existing from the previous project. The five new openings were

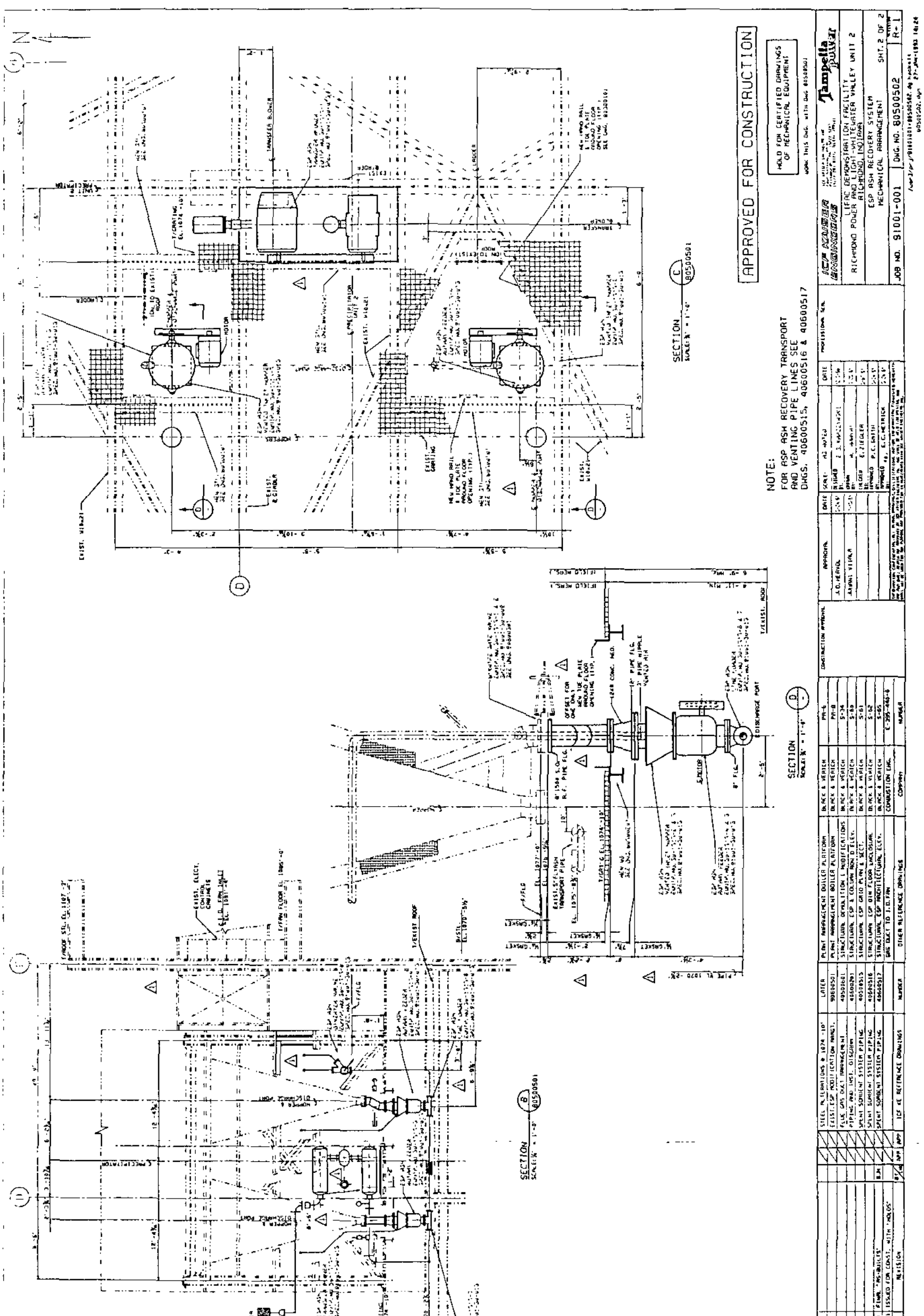


Figure 3-8 ESP Recycle Area

designed with the need to cut and replace only two boiler tubes per opening. The resulting opening is fitted with a mounting frame for the injection nozzle and has bolt holes to accommodate a typical boiler inspection door if necessary. This was the single boiler modification required for LIFAC.

3.3.2 Ductwork

The treatment of flue gas in a vertical humidification chamber located outside the boiler house necessitated a modification to the plant's ductwork on Unit No. 2. After the air preheater and before the ESP, two sections of ductwork were added for the gas inlet and outlet to the reactor. Each section has a motor actuated louver-type damper to direct the gas flow. Another motor actuated louver-type damper was installed in the plant's ductwork between the inlet and outlet dampers to eliminate gas bypass of the reactor vessel.

3.3.3 Utilities

The utility services required by the LIFAC process consist of plant water, instrument air and steam. Steam is supplied by a tie-in to the plant's medium pressure steam line from Unit No. 2. The connection has a manually operated gate valve at the tap point to isolate the plant's system from LIFAC's. The water supply for humidification has two sources: one is the plant's recirculating water system (between cooling towers and condensers), and the other is river water supply. Both lines have manually operated gate valves for isolation purposes. Desiccant air is required for instrumentation purposes and for the vent filters and baghouses in the limestone area.

3.3.4 Electrical and Control Systems

The major modification to the plant's electrical and control systems was the addition of a new ID fan controller. The existing control system used the boiler draft signal to control dampers in the ductwork to maintain the proper boiler pressure. The ID fan runs at a constant speed. The new LIFAC control scheme required the installation of a variable frequency drive (VFD) which controls the ID fan speed according to the boiler draft signal. This increases the capacity of the ID fan, which is needed to compensate for the increased pressure drop caused by the LIFAC system. The design of the new system includes a backup to the plant's original system. The VFD can then be bypassed if it required repair or service during a LIFAC outage.

3.3.5 Miscellaneous

Several other minor plant modifications were included in the design criteria to accommodate LIFAC. In the ESP area for Unit No. 2, pipe spools were included on two of the four ash hoppers for collection of ESP ash for recycling purposes. The pipe spools each have a manually operated knife gate valve to isolate the hoppers from the ash rotary feeders and collection system.

Modifications to the plant's steel work accommodate the design and installation of LIFAC equipment. The ductwork and stair tower steel located east of the power plant is tied to its structural steel by penetration of the outer brick wall in six places. An additional platform was included inside the boilerhouse at the lower injection level to support the secondary air blower. Access to numerous sampling ports and instrumentation was facilitated by new platforms and some extra lighting around the boiler and ductwork inside the power plant.

4.0 DETAILED PROCESS DESIGN

4.1 Plot Plan and Plant Layout

Figure 4-1 is the site plan RP&L's Whitewater Valley utility power plant. The site plan is provided to show the actual arrangement of LIFAC's equipment and building relative to the host facility.

4.2 Material Balance

A LIFAC overall block flow diagram is used to show a material balance for the entire desulfurization system. Figure 4-2 also depicts how the LIFAC process streams interact with the host utility. The values shown on the block diagram are based on the design basis presented in Section 3.0 of this report and a peak boiler load of 65 MW.

4.3 Process and Instrumentation Diagrams

The process and instrumentation diagrams (P&IDs) of the LIFAC demonstration consist of two drawings. Figure 4-3 is a P&ID for the instrumentation surrounding the activation reactor and ESP recycle areas; and Figure 4-4 represents the instrumentation for the limestone storage, handling, and injection areas.

4.4 Process Equipment Arrangement

A breakdown of the major process equipment for LIFAC was generated by dividing the system into four distinct areas where most of the equipment is located. Table 4A shows a listing of all major items involved in the process (refer to Figure 4-6 for item locations). The quantity, manufacturer, capacity, and materials of construction are provided for each item. Horsepowers are also shown for the motorized items which are directly related to the process. Total connected horsepower of the LIFAC system installed at RP&L is 986 Hp (736 kW). However, some installed equipment such as the secondary air fan was not been operated during the demonstration. This was based on Tampella's experience and recommendations that it would not have any improvement on performance. Hence, the predicted power consumption of the demonstration is ≈ 486 Hp (362 kW). The majority of this equipment was constructed using carbon steel. Certain applications required the use of stainless steel for potentially acidic or corrosive environments.

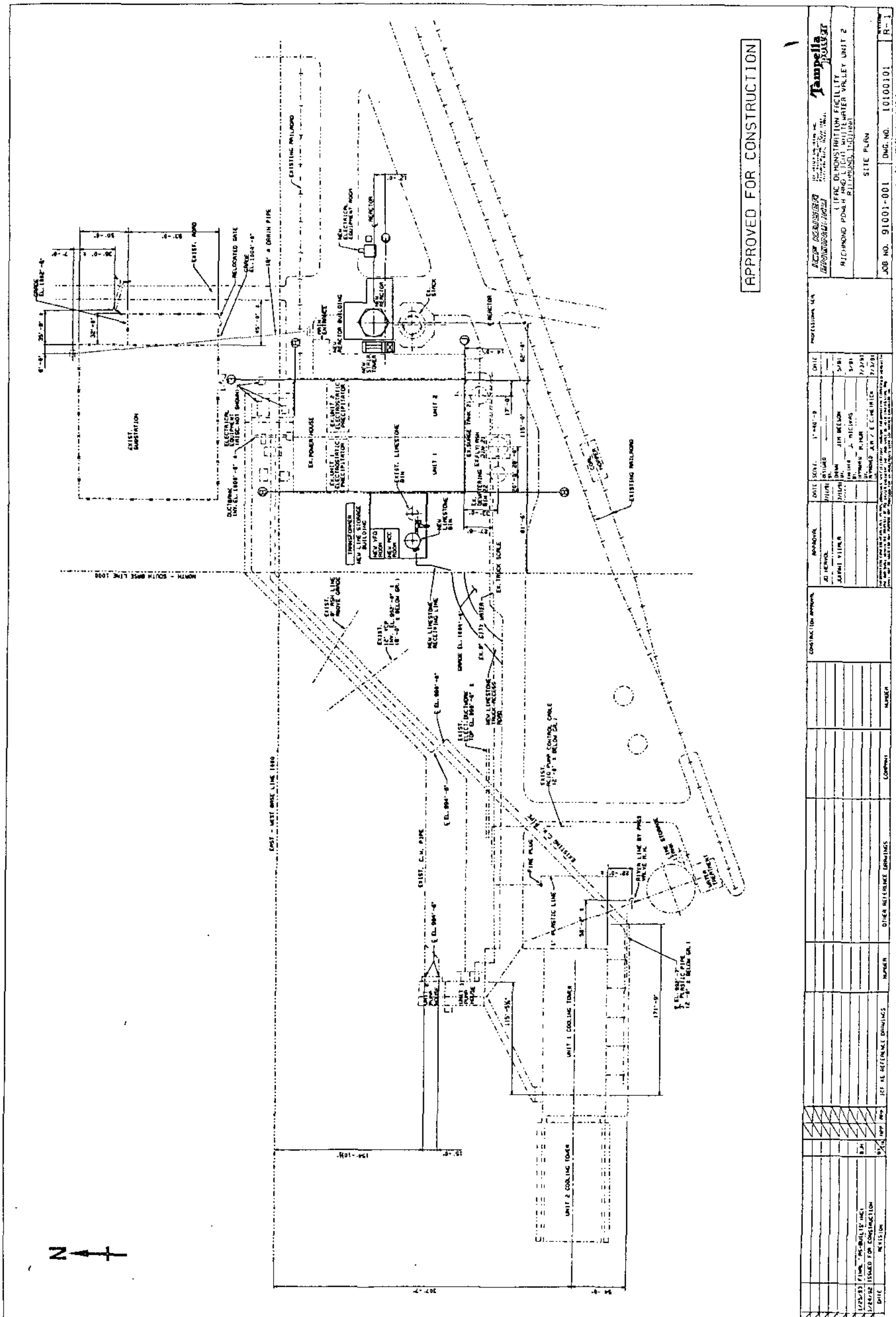
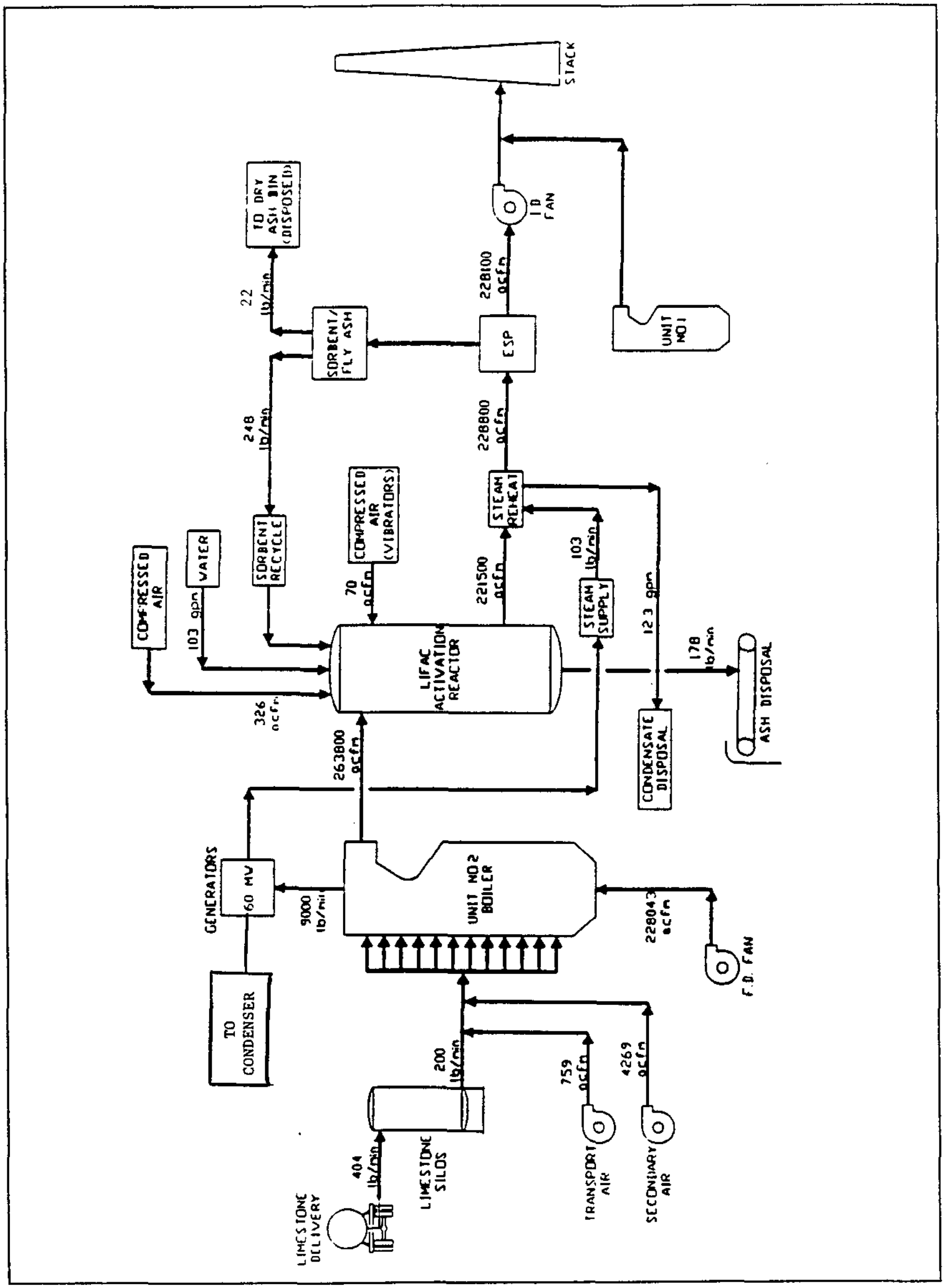


Figure 4-1 Site Plan at Richmond Power and Light

Figure 4-2 LIFAC Overall Block Flow Diagram



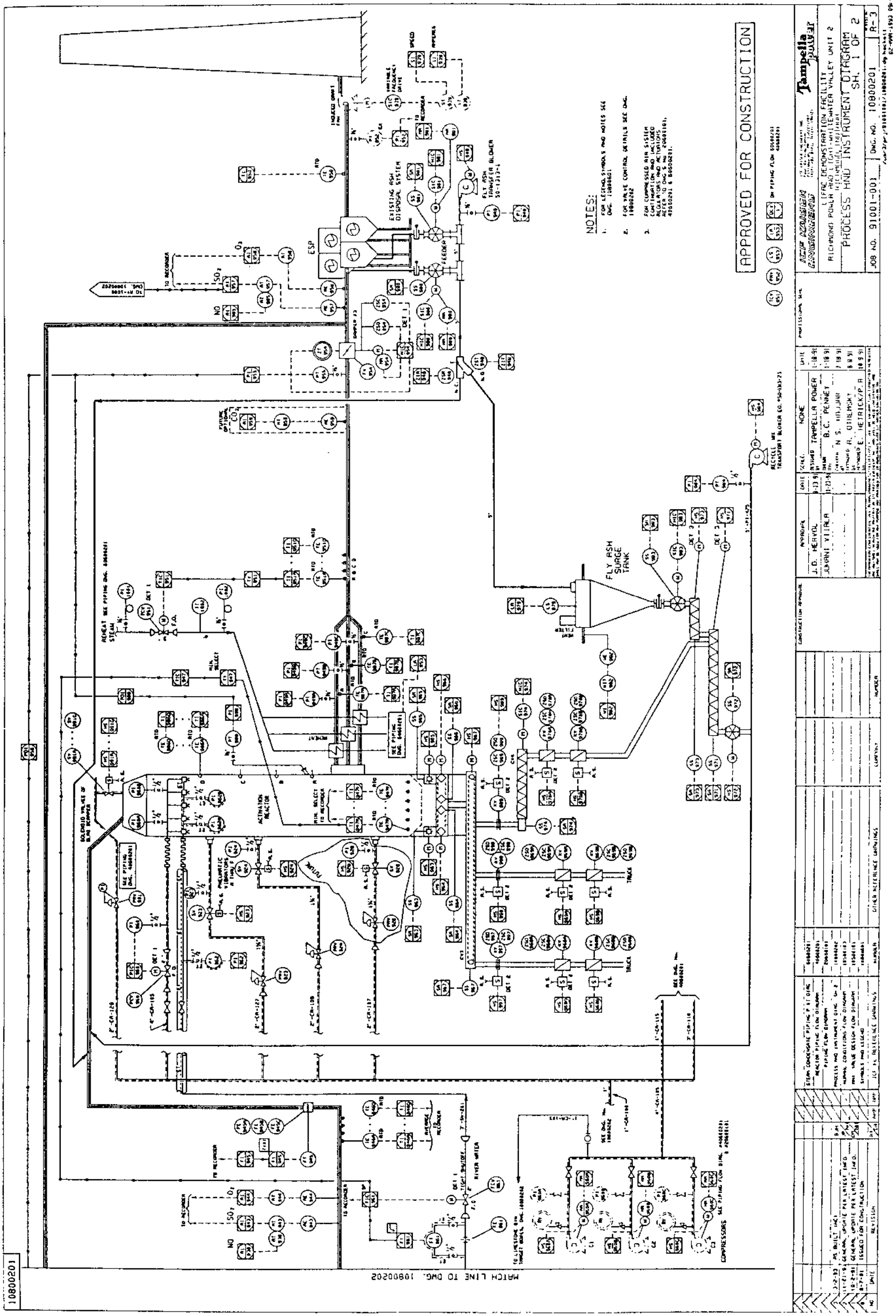


Figure 4-3 Process and Instrumentation Diagram (1 of 2)

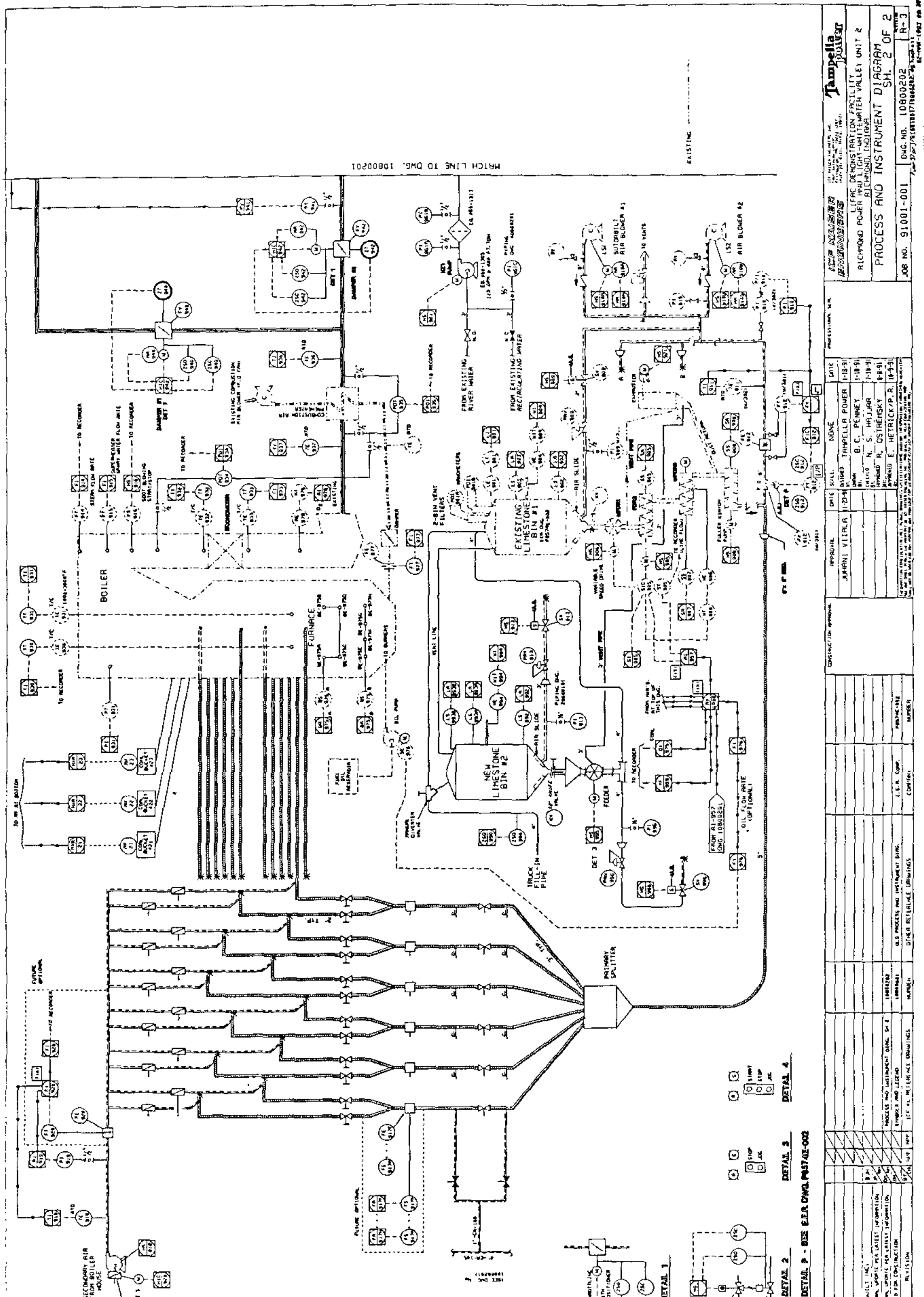


Figure 4-4 Process and Instrumentation Diagram (2 of 2)

TABLE 4A

LIFAC PROCESS EQUIPMENT AT RP&L
(Refer to *Figure 4-6* for *Item Locations*)

Item #	Item Name	Quantity	Vendor	Size/Capacity	Total Hp	Materials of Construction
LIMESTONE HANDLING AREA						
1	Diverter Valve	1	Kice	417 lb/min	--	Carbon Steel
2	Storage Silo	1	ICF Kaiser/Enerfab	576,000 lbs	--	Carbon Steel
3	Feed Silo	1	Existing	270,000 lbs	--	Carbon Steel
4	Rotary Feeders	2	Wm. W. Meyer & Sons	400 & 300 lb/min	1/5	Cast Iron/Carbon Steel
5	Screw Feeder	1	Acrison Inc.	300 lb/min	1	Stainless Steel
6	Weigh Feeder	1	Acrison Inc.	300 lb/min	0.5	Stainless Steel
7	Fuller-Kinyon Pump	1	Fuller Company	300 lb/min	25	--
8	Flow Control Valve	1	Fisher Controls	8″ Butterfly	--	--
9	Limestone Transport Blower	1	Roots-Dresser	1600 acfm	125	--
BOILER INJECTION AREA						
10	Sorbent Splitters	1/6	Lenton Industries	--	--	Carbon Steel
11	Injection Nozzles	12	Nutana Machine LTD	--	--	Stainless Steel
12	Secondary Air Fan	1	Phelps	6700 scfm	100	--
13	Dampers	4	Damper Design	--	--	Carbon Steel
ACTIVATION RECTOR AREA						
14	Feedwater Pump	1	Goulds Pumps, Inc.	115 gpm	30	--
15	Compressors	3	Ingersoll-Rand	125 psig ea.	600	--
16	Activation Reactor	1	ICF Kaiser/Enerfab	h=133′, d=28′	--	Stainless Steel
17	Humidification Nozzles	29	Spraying Systems Inc.	30:1.5 gpm (air/water)	--	Stainless Steel
18	Nozzles Housings	7	Nutana Machine LTD	--	--	Carbon Steel
19	Vibrators	13	Navco	1500 Hz @ 60 psi	--	--
20	Flue Gas Reheaters	3	Thermatics	570 F/246 psig	--	Stainless Steel Pipe
21	Crushers	2	Process Equipment	22 tph	40	Carbon Steel
22	Discharge Conveyors	2	Process Equipment	22 tph	14	Stainless/Carbon Steel
23	Transfer Conveyor	1	Process Equipment	22 tph	3	Carbon Steel
24	Knife Valves	2	Process Equipment	18″ × 30″	--	Carbon Steel
25	Slag Gate Valves	2	Process Equipment	18″ × 30″	--	Carbon Steel
26	Control Valves air, water, steam)	3	Fisher Controls	--	--	--

TABLE 4A (Continued)

LIFAC PROCESS EQUIPMENT AT RP&L
(Refer to Figure 4-6 for Item Locations)

Item #	Item Name	Quantity	Vendor	Size/Capacity	Total Hp	Materials of Construction
ESP RECYCLE AREA						
27	Sorbent Recycle Blower	1	Sutorbilt	890 acfm	40	--
28	Rotary Feeders	2	Detroit Stoker co.	10 tph	1.5	Cast Iron/Carbon Steel
29	Gate Valves	2	DeZurick	12″ Manual	--	Stainless Steel
30	Process Monitoring and Control System	1	ICF Kaiser/Tampella	--	--	--

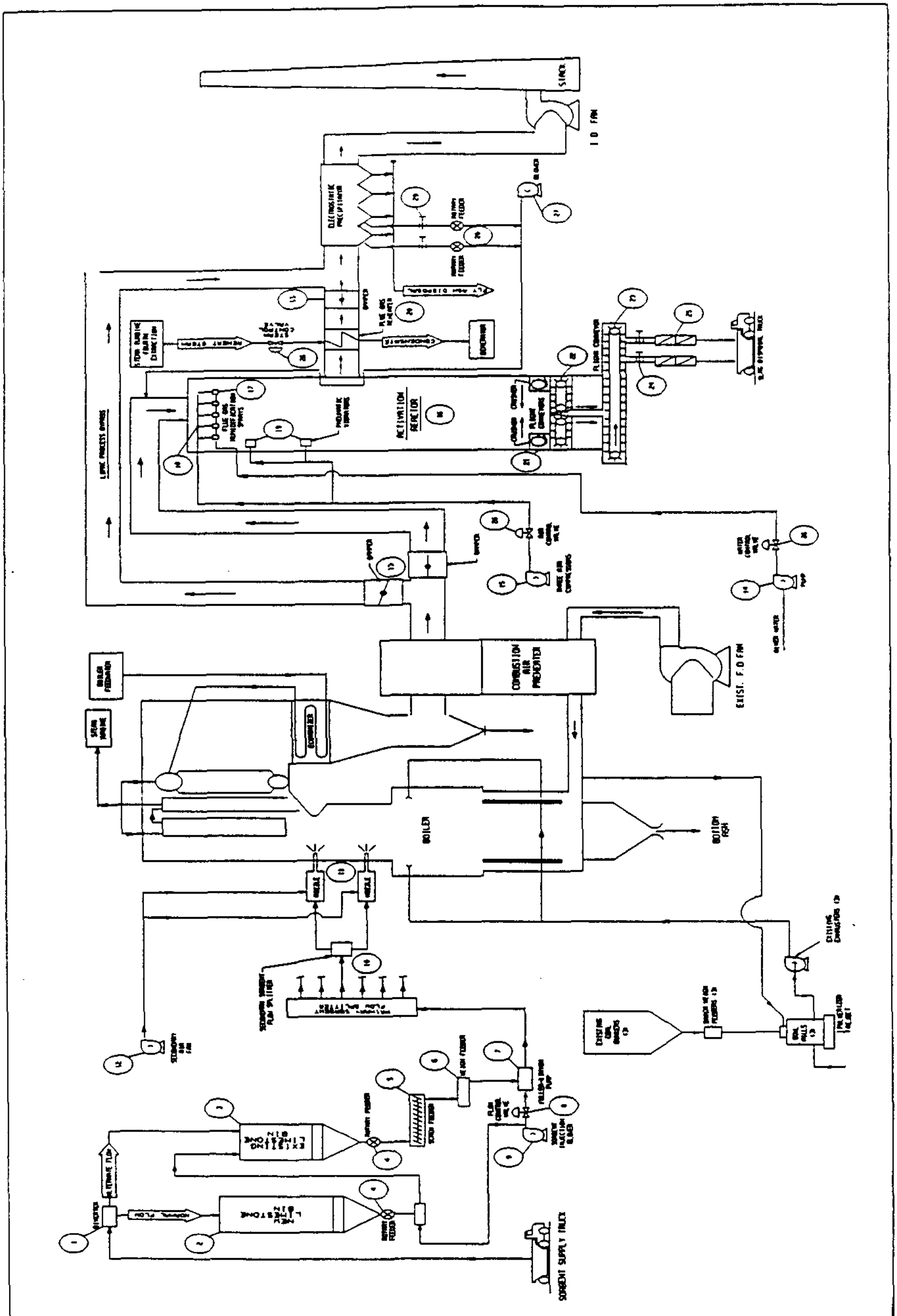


Figure 4-6 Location of Major LIFAC Equipment

4.5 Waste Streams and Their Disposal

Under the Environmental Monitoring, all waste streams impacted by the technology have been monitored before, during and after LIFAC operations. These waste streams include ash from the economizer, LIFAC reactor bottom hopper, ESP hoppers (front and back) and the boiler bottom ash disposal bin. All but the LIFAC ash was and still is disposed by RP&L by transporting it by truck from the ash disposal bin to an approved landfill. LIFAC ash was trucked off-site separately. It was collected at the bottom of the reactor in dumpsters then hauled to an approved landfill by the LIFAC partnership.

Another waste stream is the water from the boiler bottom which is discharged to the ash disposal bin, and then goes to the power plants pond system. This waste stream was monitored by RP&L at the pond outfall under their NPDES Discharge permit. However, we also monitored this discharge at the ash disposal bin due to the concern of a long residence time through the pond system and inability to verify any impacts. No impact was evident based on the time frame our monitoring was conducted.

Results of all monitoring of ash, feed water, and discharge water are in the Final Report Volume 2: Project Performance and Economics.

5.0 PROJECT CAPITAL

The capital cost breakdown of the LIFAC installation at RP&L is unique. Since this installation was a retrofit to an existing facility and installed at the site of an earlier FGD demonstration, it is necessary to present a detailed structure of capital spending. Table 5A shows the total capital cost of the LIFAC unit as it was installed. Engineering, reactor fabrication and erection, and structural/ mechanical/piping consumed over half the capital expenditures. The total capital cost of the LIFAC demonstration at RP&L was approximately $8,101,000. Table 5B presents cost to purchase all materials.

Since RP&L was the site of an earlier FGD demonstration, capital cost savings were experienced. The equipment from the previous demonstration was donated to LIFAC. Each piece of equipment was selected to be utilized based on its operability and reliability for the LIFAC demonstration. This equipment can easily be replaced when LIFAC advances into a commercial operation mode at RP&L. The reactor ash disposal system was built for demonstration purposes only. Additional capital needs to be spent on ash conveyors and a storage silo before commercial operation. No back-up systems were installed as part of the demonstration. A commercial unit would require some redundancy systems such as a backup water pump, and spare I/O cards for process control system.

The demonstration nature of the project required additional capital expenditure. The LIFAC demonstration program incorporated many testing and measuring techniques. For this reason, additional instrumentation and data collection devices were purchased and utilized. Supplementary sampling ports and man doors were also required for the demonstration in order to inspect and assess the process' impact on the reactor and the ductwork. Five limestone injection ports were installed on the boiler's walls to test several combinations of injection settings.

Additional capital costs also ensued as a result of retrofitting the LIFAC process to an existing facility. Extra engineering, construction, and equipment costs were realized. The following is a breakdown of additional costs encountered as a result of retrofitting:

<u>Layout</u>

- Erected a building around existing RP&L limestone storage and handling equipment
- Provided two motor control centers

TABLE 5A

CAPITAL COST OF THE RICHMOND LIFAC UNIT AS INSTALLED (BASE YEAR 1993)

CAPITAL COST	
Equipment & Materials	
Limestone Handling & Storage	$ 160,000
Activation Reactor & Ductwork	$ 669,000
Sorbent Recycle System	$ 67,000
Electrical/Instrumentation	$ 272,000
I.D. Fan Upgrade	$ 255,000
Total Equipment & Materials	**$ 1,423,000**
Subcontracts:	
Foundations	$ 324,000
Reactor Fab. & Erection	$ 1,670,000
Structural/Mechanical/Piping	$ 1,569,000
Electrical/Instrumentation	$ 574,000
Insulation & Cladding	$ 268,000
Miscellaneous Fabrication	$ 573,000
Total Subcontractors	**$ 4,978,000**
Engineering:	$ 1,200,000
Management & Administration:	$ 300,000
Construction Supervision:	$ 200,000
Total Capital Cost	**$ 8,101,000**

Table 5B *Procurement Cost and Budgets - Equipment, Materials and Subcontracts - Budget Period II Commitments*

Activity No	Description	P.O. Number	Supplier	P.O. Amount	Freight	Current Commitment
C9006	Transformers	91001-1012	Richmond Power & Light	($0.00)	$0.00	($0.00)
C9003	Flue Gas Analyzer Parts	91001-1026A	Lear Siegler	$1,169.30	$33.75	$1,203.05
C4004	Expansion Joints	91001-1027B	Dynex	$3,564.00	$77.50	$3,641.50
C4004	Isolation Damper	91001-1027C	Damper Design Inc.	$6,980.00	$697.70	$7,677.70
C4004	Actuator Parts and Installation	91001-1027D	Damper Design Inc.	$2,000.95	$0.00	$2,000.95
R0012	ESP Inspection	91001-1028	Lodge-Cottrell	$4,800.00	$0.00	$4,800.00
R0013	Particulate Emission Modeling	91001-1033	Meteorological Evaluation Ser.	$4,975.00	$0.00	$4,975.00
C9014	Temperature Transmitters	91001-1035A	Andrews Industrial Controls	$320.00	$16.10	$336.10
C9012	Temperature Elements	91001-1038	Ram Sensors	$2,517.66	$35.16	$2,552.82
C9013	Pressure Indicators	91001-1043A	Thermoflo Equipment Co.	$241.78	$11.23	$253.01
C9027	Flow Element - Flue Gas	91001-1045A	Measurement Instruments East	$922.00	$0.00	$922.00
R0014	Stack Gas Sampling	91001-1046	Keystone Environmental	$16,200.00	$0.00	$16,200.00
R0017	Sutorbuilt Blower Inspection	91001-1047	Indiana Bulk & Pneumatics	$520.00	$0.00	$520.00
R0018	Acrison Weigh Feeder Inspection	91001-1048	Acrison Inc	$2,204.35	$0.00	$2,204.35
R0019	Compressor Inspection	91001-1049	Ingersoll Rand Corp	$1,099.50	$0.00	$1,099.50
R0019	Compressor Inspection	91001-1049B	Ingersoll Rand Corp	$1,205.20	$0.00	$1,205.20
R0019	Compressor Repairs	91001-1049C	Ingersoll Rand Corp	$1,490.26	$0.00	$1,490.26
R0019	Compressor Repairs	91001-1049D	Ingersoll Rand Corp	$213.35	$0.00	$213.35
R0019	Compressor Repairs	91001-1049E	Ingersoll Rand Corp	$1,989.36	$0.00	$1,989.36
R0020	Fuller Kinyon Pump Inspection	91001-1050	Fuller Company	$0.00	$0.00	$0.00
R0015	Fuller Kinyon Pump Parts	91001-1051	Fuller Company	$1,566.00	$35.35	$1,601.35
R0016	Conveyor Chain Lubrication	91001-1052	Tribology Tech-Lube	$2,410.20	$199.38	$2,609.58
R0018	Air Compressor Parts and Oil	91001-1053	Ingersoll Rand Corp	$5,266.90	$9.33	$5,276.23
C2008	Root's Air Blower	91001-1055	Airtek Inc.	$13,925.00	$0.00	$13,925.00
R0021	Flue Gas Probes	91001-1056	Napp, Inc	$4,823.00	$147.58	$4,970.58
R0022	Calibration Gases	91001-1057	Beck's Welding Supply	$6,000.00	($487.80)	$5,512.20
R0023	Signal Isolators	91001-1058	Instrument Services Inc	$1,638.00	$18.50	$1,656.50
R0024	CO2 and O2 Analyzers	91001-1059	VWR Scientific	$852.50	$71.10	$923.60
R0025	Span Potentiometer	91001-1060	Ametek Pressure Measurement	$60.00	$23.50	$83.50
R0026	Analog Input Module	91001-1061	Tri-State Supply Co.	$916.50	$19.25	$935.75
R0026	Analog Input Module Repair	91001-1061A	Tri-State Supply Co.	$1,365.00	$19.25	$1,384.25
R0027	Zero Speed Switch	91001-1062	Hobdon Schilbe & Smith	$505.00	$26.55	$531.55
R0028	Water & Solid Waste Analysis	91001-1063	Antech Ltd.	$35,000.00	($1,002.62)	$33,997.38
R0029	Stack Gas Sampling Equipment	91001-1064	Keystone Environmental	$10,000.00	($7,971.98)	$2,028.02
R0030	Pilot Operated Solenoid Valve	91001-1065	T. F. Cambell Co.	$470.00	$31.45	$501.45
R0031	Ashcroft Pressure Gage	91001-1066	M. S. Jacobs & Associates	$36.00	$13.70	$49.70
R0032	Calibration Adapter Plug	91001-1067	Equipment and Controls	$51.00	$13.50	$64.50
R0034	Oxygen Monitor Rental	91001-1068	Response Rentals	$3,000.00	($2,668.23)	$331.77
R0035	ASCO Replacement Diaphragm	91001-1069	T. F. Campbell	$33.50	$14.25	$47.75
R0036	Sample Containers	91001-1070	Warehouse Paint Centers	$2,000.00	($1,532.00)	$468.00
R0037	Control Valve Parts	91001-1071	Equipment & Controls	$277.71	$0.00	$277.71
R0038	Crushed Limestone	91001-1072	Rodgers Group	$20,903.23	$0.00	$20,903.23
R0039	Portable Radios	91001-1073	Communications Unlimited	$1,054.00	$12.00	$1,066.00
R0040	I/P Replacement Parts	91001-1074	Equipment and Controls	$161.93	$0.00	$161.93
R0041	Coal & Ash Analyses	91001-1075	Standard Laboratories	$20,000.00	($5,273.84)	$14,726.16
R0042	Switchgear Relays	91001-1076	Verhill Associates	$184.00	$0.00	$184.00
R0043	Electrical Parts	91001-1077	Grant Industrial Controls	$178.01	$41.00	$219.01
R0044	Analyzer Repairs	91001-1078	Lear Siegler	$822.00	$130.70	$952.70
R0045	Hoist and Chain Fall	91001-1079	Mazzella	$646.60	$15.95	$662.55
R0046	Transmitter - ID Fan Speed	91001-1080	Rosemount	$474.00	$19.25	$493.25
R0047	Analyzer Fittings	91001-1081	Indianapolis Valve & Fitting Co.	$109.80	$0.00	$109.80
R0048	Sample Port Installation	91001-1082	H.J. Osterfeld	$3,717.00	$0.00	$3,717.00
R0048	Injection Piping Installation	91001-1082A	H.J. Osterfeld	$12,932.00	$0.00	$12,932.00
R0048	Control Valve Piping Installation	91001-1082B	H.J. Osterfeld	$1,245.00	$0.00	$1,245.00
R0049	Chart Paper & Cartridge	91001-1083	Instrument Sales & Service	$293.85	$3.70	$297.55
R0050	Chart Paper & Pens	91001-1084	Ray Knitter Associates	$225.75	$5.26	$231.01

Table 5B, page 2

Activity No	Description	P.O. Number	Supplier	P.O. Amount	Freight	Current Commitment
R0051	LIFAC Ash Handling	91001-1085	Rumpke	$150,000.00	($41,072.35)	$108,927.65
R0052	Electrical Relays	91001-1086	Grant Industrial Controls	$61.60	$2.24	$63.84
R0053	Analyzer Calibration	91001-1087	Lear Siegler	$2,051.00	$0.00	$2,051.00
R0054	Certified Smoke Reader	91001-1088	Crawfordsville EL & P	$525.73	$0.00	$525.73
R0055	Opacity Monitoring & Consulting	91001-1089	Mostardi-Platt Associates, Inc	$18,104.76	$0.00	$18,104.76
R0055	Opacity Monitoring & Consulting	91001-1089C	Mostardi-Platt Associates, Inc	$18,142.00	$0.00	$18,142.00
R0055	Opacity Monitoring & Consulting	91001-1089D	Mostardi-Platt Associates, Inc	$103,940.00	($64,684.60)	$39,255.40
R0056	Sorbent Injection Hose	91001-1090	Specialty Hose Corp	$2,504.70	$117.35	$2,622.05
R0057	MOHR INC	91001-1091	Crane Rental	$1,240.00	($322.00)	$918.00
R0058	Ross Hills Controls	91001-1092	VFD Service	$1,500.00	($1,500.00)	$0.00
R0059	Limestone Supply	91001-1093	Cosmos Cement	$160,000.00	($19,495.50)	$140,504.50
R0060	Repair Air Conditioning System	91001-1094	Fuller Engineering Services	$361.05	$0.00	$361.05
R0060	Repair Air Conditioning System	91001-1094A	Fuller Engineering Services	$1,192.50	$0.00	$1,192.50
R0060	Repair Air Conditioning System	91001-1094B	Fuller Engineering Services	$500.00	($500.00)	$0.00
R0061	Repair Pressure Transmitter	91001-1095	Rosemount, Inc	$800.00	($682.17)	$117.83
R0062	Water Control Valve	91001-1096	Equipment & Controls	$3,363.00	$0.00	$3,363.00
R0063	Signal Isolators	91001-1097	EIL Instruments	$732.00	$11.98	$743.98
R0064	Signal Isolator/Convertor	91001-1098	Gilson Engineering	$205.00	$3.58	$208.58
R0065	Pneumatic Tugger Rental	91001-1099	Oberle and Associates	$4,000.00	($2,758.84)	$1,241.16
R0066	Electro-Pneumatic Transducer	91001-1100	M.S. Jacobs & Assoc. Inc.	$407.00	$4.29	$411.29
R0067	Roof Repairs	91001-1101	Mid-Miami Roofing	$3,196.50	$0.00	$3,196.50
R0068	Flue Gas Reheat Study	91001-1102	Black & Veatch	$2,920.00	$0.00	$2,920.00
R0069	Filter Cartridges	91001-1103	Dynamic Air Conv. Systems	$672.00	$42.08	$714.08
R0070	Pneumatic Tugger Rental	91001-1104	F & M Supply	$3,000.00	$1,712.25	$4,712.25
R0072	RTD Temperature Detectors	91001-1105	The Ginger Bonfili Co	$282.00	$68.90	$350.90
R0073	Particle Size Analyses	91001-1106	Penn State University	$15,000.00	($12,220.80)	$2,779.20
R0075	Proximity Limit Switches	91001-1107	Denko Engineering	$864.00	$22.00	$886.00
R0076	Waste Disposal	91001-1108	Chemical Waste Management	$50,000.00	($19,718.26)	$30,281.74
R0077	High Pressure Cleaning	91001-1109	Miami Valley Services	$6,185.50	$3,592.50	$9,778.00
R0078	Solenoid Valves	91001-1110	TriState Supply	$328.00	$15.00	$343.00
R0079	460V Transformer	91001-1111	Horner Electric	$48.75	$3.27	$52.02
R0080	Inverter Repair	91001-1112	Horner Electric	$856.10	$39.45	$895.55
R0081	Weigh Feeder Repairs	91001-1113	Acrison	$31.26	$27.35	$58.61
R0081	Weigh Feeder Repairs	91001-1113A	Acrison	$2,971.10	$0.00	$2,971.10
R0071	Project Computer	91001-16073	Gateway 2000	$1,995.00	$425.22	$2,420.22
R0002	Steel, Mechanical, Piping Inst.	91001-3002-6	Enerfab Inc	$19,627.64	$0.00	$19,627.64
R0002	Steel, Mechanical, Piping Inst.	91001-3002-7	Enerfab Inc	$14,026.23	$0.00	$14,026.23
R0002	Steel, Mechanical, Piping Inst.	91001-3002-8	Enerfab Inc	$518.74	$0.00	$518.74
R0002	Steel, Mechanical, Piping Inst.	91001-3002-9	Enerfab Inc	$1,640.94	$0.00	$1,640.94
R0003	Mechanical Repairs	91001-3004	Oberle & Associates	$8,509.08	($5,639.00)	$2,870.08
R0001	Electrical & Instrumentation	91001-3005	Cummins Electric	$8,785.61	$0.00	$8,785.61
R0001	Electrical & Instrumentation	91001-3005	Cummins Electric	$14,927.18	$0.00	$14,927.18
R0007	Insulation and Lagging	91001-3006	Kramig Co.	$2,380.58	$0.00	$2,380.58
R0033	Stack Sampling	91001-3007	Keystone Environmental Res.	$18,497.31	$0.00	$18,497.31
R0074	Reheat Duct Installation	91001-3008	Kennedy Tank & Mfg. Co.	$12,153.00	$0.00	$12,153.00
			TOTAL PERIOD II	$864,603.05	($179,700.54)	$684,902.51

Indicates a New or Revised Commitment in the Current Month

- Modified ESP ductwork with vanes and baffle plates
- Erected additional stairs in boiler house
- Extensively routed ductwork to/from reactor

Construction

- Some work was performed only during boiler outages
- Rerouted some existing plant piping
- Rerouted some existing plant electrical cables
- Cleanup after construction (paving, grass, painting, etc.)

Equipment

- Repaired, replaced, and calibrated existing RP&L limestone storage and handling equipment
- Installed additional limestone silo for increased capacity
- Installed a stand-alone process control system
- Installed a VFD to increase ID fan efficiency
- Added an instrument air compressor for LIFAC instrumentation
- Installed moisturizing screw conveyor on ESP ash disposal silo
- Changed ESP fly ash removal from hydroveyor to blower-operated vacuum system

Fabrication of LIFAC's process elements was performed both in the shop and on-site. Prefabrication was initiated by the subcontractors at their respective facilities prior to shipment. Most of the structural steel applications were prefabricated including: reactor support, stair tower, reactor building, and the limestone building. All steel structures were provided with bolted connections. The steel was prepainted; only touchup painting was required at the site. It was necessary for certain sections of ductwork to be assembled in the shop. Ducts were composed of flanges for easy bolt connections. No on-site painting of the ductwork was necessary.

On-site fabrication was performed on the grounds of RP&L before erection. Most of the activation reactor vessel was assembled at RP&L. The humidification (top) and discharge (bottom) sections of the LIFAC reactor were prefabricated, cut in half, shipped to the site, then assembled before installation. Each circular section of the reactor was welded on-site from three arcs, each one-third of the total circumference. The reactor and ductwork were fitted with insulation and cladding prior to erection. The remaining process equipment was shipped to the site installation.

Table 5C presents estimated costs of the existing equipment which was incorporated into the LIFAC Project. (Note that these costs represent what it would cost to purchase and install these items as part of the project, if they were not existing).

TABLE 5C

ESTIMATED COSTS FOR EXISTING EQUIPMENT INCORPORATED INTO THE LIFAC PROJECT

Existing equipment		
125-ton Storage Silo	$	106,400
Limestone Feeding System	$	694,600
Two Vent Baghouses	$	20,400
TOTAL COSTS	**$**	**821,400**

Also, the additional cost incurred because this was a demonstration project is estimated at $534,100. This basically includes 75% of the environmental costs which is included under engineering in Table 5A with the required monitoring, and also approximately 25% of project management/ administration.

6.0 PROCESS OPERATING COST

6.1 Fixed Operating Cost

During the two-year demonstration period, the project required a surplus of operating and test personnel. Two additional operators per shift were required for the test phase of the project, while a unit in commercial operation would require a limited operating staff. Minor maintenance tasks were performed by the test team and the RP&L maintenance crew. Major repairs or modifications were executed by subcontractors. The LIFAC process was demonstrated over short operation periods, from one day to three weeks of testing. Except for the onset of unexpected repair, maintenance costs were expected to be low during the 2800 hours of the demonstration period. Table 6A shows the estimated annual fixed operating and maintenance cost of the RP&L LIFAC unit in continuous operation. The total fixed O&M cost was approximately $581,200.

6.2 Variable Operating Cost

Variable operating cost includes all the commodities necessary for process operation. The major variable cost, which are presented in detail in Table 6B, consist of limestone, waste disposal, energy, and water. These values are based on operating the power plant at full load (60 MW). Limestone delivery contracts for the demonstration were short-term with the two suppliers located 150 and 250 miles from Richmond. This type of contract and distance from the site induce higher limestone prices. However, local limestone suppliers do not have the capacity or required quality for the demonstration. The price of limestone ranged from $26/ton to $37/ton, whereas the average commercial value of limestone is about $15/ton. Ash disposal cost was expected to vary during testing. Disposal cost is dependent upon the waste management company and landfill used. The price was expected to range between $11/ton and $35/ton.

Energy costs involve auxiliary power consumed by the process equipment and the reheating of exiting flue gas using medium pressure steam. The total connected horsepower for LIFAC is 736 kW. However, some equipment was not used continuously for the demonstration, and the estimated average consumption of auxiliary power was approximately 362 kW. Steam was used to reheat the flue gas prior to entering the ESP. Nearly 100 lb/min of medium pressure was needed to increase the gas temperature 35°F. Water was provided by RP&L from the Whitewater River or plant recirculation system.

TABLE 6A

ESTIMATED ANNUAL FIXED OPERATING COST UNDER CONTINUOUS OPERATION

ANNUAL FIXED OPERATING COSTS, CONTINUOUS		
Operating Labor Cost Details:		
Number of Operators Per Shift	2	
Number of Shifts Per Week	4.2	
Operating Pay Rate $/Hour	25	
		Cost, $/Year
Total Annual Operating Labor Cost		$499,200
Total Annual Maintenance Labor Cost		$25,000
Total Annual Maintenance Material Cost		$50,000
Total Annual Adminstrative and Support Labor Cost		$7,000
Total Annual Fixed O&M Cost		$581,200

TABLE 6B

ESTIMATED VARIABLE OPERATING COST UNDER NORMAL CONDITIONS

VARIABLE OPERATING COSTS (65 MW, NORMAL FLOW)				
Commodity	*Unit*	*$/Unit*	*Quantity/hr*	*$/hr*
Limestone	tons	35.00	6	210.00
Reheat Steam	lbs	0.003	6,180	18.50
Water	gals	0.00	6,180	0.00
Auxiliary Power	kWh	0.02	360	7.20
Ash Removal	tons	17.00	5.4	91.80
Total Variable Operating Cost				**327.50**

Total Planned Operating Hours for Demonstration	**2,800**

6.3 Startup and Checkout Cost

The startup and checkout period was initiated shortly after baseline testing in September of 1992. Since the process is easy to start up and shut down, all checkouts were performed by operating the process for short periods of time. Most shakedown activities were accomplished by LIFAC personnel. Some equipment, especially the remaining EER units (from the LIMB tests), needed the attention of manufacturers' representatives for calibration or repair. RP&L maintenance also helped to expedite the checkout process. The approximate startup cost of the LIFAC process is shown in Table 6C. The startup cost of the demonstration was about $200,000.

An extra set of gas analyzers were rented for calibration and verification. The limestone feeding system was calibrated by continuously filling a large bucket with limestone and observing the change in silo weight. It was discovered during the startup phase that some items needed modifications due to the following problems: the ID fan's variable frequency drive failed several times; the flue gas dampers were sticking; the steam reheat condensate return system was inoperable; and the water control valve and ESP recycle rotary feeders were the wrong type.

The process control system was calibrated via the process computers in the RP&L control room while LIFAC was operating at reduced flows.

Several training classes were held for RP&L personnel to educate them on the various principles and operating procedures of the LIFAC process.

TABLE 6C

ESTIMATED STARTUP COST OF THE LIFAC SYSTEM

Startup Cost Element	Cost, $
Operating Labor Cost	$110,000
Maintenance and Materials Cost	$38,500
Administrative and Support Cost	$38,500
Commodity Cost:	
Limestone	$6,250
Reheat Steam	$5,400
Water	$0
Power	$1,600
Ash Removal	$4,250
TOTAL	**$204,500**

Length of Startup Period, months	**2**

7.0 COMMERCIAL APPLICATIONS

The LIFAC FGD system has a relatively low overall cost due to the simplicity of the process and low operation costs. The drawbacks of the process are a low sorbent utilization rate (~40%) and a moderate SO_2 removal rate (75 to 85%). The limestone sorbent used with LIFAC is cheaper and easier to handle than other, more efficient FGD processes. Although LIFAC units have been installed with new boilers on two occasions, it is primarily installed as a retrofit. Existing power plants and industrial facilities do not have the rigid emissions limits which are associated with new facilities. Also, existing plants have limited space available for FGD systems. A LIFAC unit can be installed with minimum space requirements and removes up to 85% of the SO_2 from a plant's emissions. The LIFAC process is easy to operate. The process monitoring system is located in the plant's control room. Controls can be incorporated into the plant's panels or isolated from plant operations.

LIFAC systems have been designed for coal-fired boilers ranging from 25 to 350 MW. The number of units needed is dependent upon the amount of flue gas generated and the size of the ESPs at the facility. A 300 MW boiler will require two LIFAC units to treat the existing gas stream, due to the units diameter and humidification.

Limestone injections into the furnace may affect certain boiler operations such as soot blowing frequency. However, its impact on the host is minimal. Limestone injection rate is dependent on the sulfur content of the combustion coal.

The ash by-product generated in the desulfurization process does not require additional treatment before dumping at a landfill. Thus, waste handling and disposal are less expensive. The by-product is dry and may need to be moistened to eliminate any dust concerns. The ash from some commercial installations has been used for concrete block production and in the mining industry.

There are several LIFAC units in operation on boilers burning various types of coal, from low Btu lignite to high Btu bituminous coal. A listing of LIFAC installation worldwide is presented in Table 7A. The first full-size LIFAC installation treating high sulfur (2.5%) coal emissions is the RP&L demonstration facility.

It is believed that LIFAC units become a less competitive option for power plant >500 MW. Based on an internal marketing study conducted by LIFAC North America, there are approximately 850

TABLE 7A

LIFAC INSTALLATIONS WORLDWIDE

Client - Plant	Country	Delivery Year	Boiler Size	Amount of Flue Gas to LIFAC Reactors	SO_2 % Removed	Ca/S Molar Ratio
Imatran Voima, Inkoo 4/1 Pilot	Finland	1986	250 MW	20%	76%	--
Nestre, Kulloo	Finland	1986	3 MW	100%	77%	2
Imatran Voima, Inkoo 4/2	Finland	1988	250 MW	50%	75-80%	2 and 2.5
Prommashimport, Baikal	Russia	1988	45 MW	100%	--	--
Imatran Voima, Inkoo 4/1	Finland	1989	250 MW	50%	--	--
Saskatchewan Power, Poplar River	Canada	1990	300 MW	50%	--	--
Richmond Power & Light, Whitewater Valley	USA	1992	60 MW	100%	--	--
Saskatchewan Power, Shand 1	Canada	1992	330 MW	50%	--	--
Kostamuksha, Mining Combine	Russia	1994	230 MW	100%	--	--
Xiaguan Power Station	China	1995	125 MW	100%	--	--

(less than 500 MW) potential units where the LIFAC technology could be applicable. It could also be noted that as long as emissions credits are around $200 per ton of SO_2 removed, the LIFAC units are not economically feasible. Emissions credits need to be in the $400/ton range to make LIFAC marketable.

8.0 REFERENCES

1. US DOE Contract No. DE-FC22-90PC90548, "LIFAC Demonstration at Richmond Power and Light Whitewater Valley Unit No. 2," March 1992.

2. LIFAC Process Evaluation Test Plan, LIFAC Sorbent Injection Desulfurization Demonstration Project presented to U.S. Department of Energy, Pittsburgh Energy Technology Center, Pittsburgh, PA, August 1992.

3. Rosse, J.; Hervol, J.; Viiala, J.; Koskinen, J.; Patel, J.; and Huffman, I; "LIFAC Flue Gas Desulfurization," presented March 1992.

APPENDIX I

COAL ANALYSIS

STANDARD LABORATORIES, INC.

Branch Code 44

Lab. No. 40446

Date Rec'd. 09/28/92

Date Sampled --------

Sampled By YOURSELVES

TAMPELLA POWER CORPORATION
P.O. BOX 365
RICHMOND, IN 47374
ATT: RICH [illegible]

SAMPLE IDENTIFICATION

BA-CF-65-090212

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB	% Sulfur
As Rec'd.	13.08	8.90	XXXX	XXXX	11343	2.38
Dry Basis	-----	10.24	XXXX	XXXX	13049	2.73
M-A-Free					14537	

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted, Mark M. Smith

MARK M. SMITH

Branch Code 44

Lab. No 40445

Date Rec'd 09/28/92

Date Sampled --------

Sampled By YOURSELVES

TAMPELLA POWER CORPORATION
P.O. BOX 356
RICHMOND, IN 47374
ATT: RICH EASLER

SAMPLE IDENTIFICATION

BA-CF-65-09230

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.35	9.09	XXXX	XXXX	11366	2.53
Dry Basis	-----	10.49	XXXX	XXXX	13118	2.92
M-A-Free					14656	

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully submitted, Mark M. Smith
MARK M. SMITH

Lab. No. 59017

Date Rec'd 09/27/93

Date Sampled 09/22/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

RECEIVED
OCT 1 3 1993
... DEPARTMENT

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #1

GRINDABILITY MOISTURE = 2.54%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	11.74	10.78	33.36	44.12	11345	2.24
Dry Basis	-----	12.21	37.80	49.99	12854	2.54
M-A-Free					14642	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2100	2525
SOFTENING	2235	2550
HEMISPHERICAL	2355	2570
FINAL	2510	2610

HARDGROVE GRINDABILITY INDEX : 54

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No.	59017
Date Rec'd	09/27/93
Date Sampled	09/22/93
Sampled By	CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
TEST #1

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

ARSENIC - 84.4 ug/g ASH BASIS

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	12.21
HYDROGEN	4.88
CARBON	72.00
NITROGEN	1.50
SULFUR	2.54
OXYGEN	6.87
CHLORINE	0.03

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	48.60
ALUMINUM OXIDE (AL2O3)	22.88
TITANIUM DIOXIDE (TIO2)	1.12
CALCIUM OXIDE (CAO)	2.48
POTASSIUM OXIDE (K2O)	1.74
MAGNESIUM OXIDE (MGO)	0.76
SODIUM OXIDE (NA2O)	0.28
PHOSPHORUS PENTOXIDE (P2O5)	0.24
FERRIC OXIDE (FE2O3)	16.68
SULFUR TRIOXIDE (SO3)	2.42
UNDETERMINED	2.80

BASE/ACID RATIO: 0.3022
LBS OF ASH/MILLION BTU: 9.50
SLAG VISCOSITY: 2550 DEG F. T250 POISE
FOULING INDEX: 0.0846 TYPE: LOW
SLAGGING INDEX: 0.7676 TYPE: MEDIUM
SILICA VALUE: 70.9282
% ALKALI AS NA2O: 0.1759

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59018

Date Rec'd. 09/27/93

Date Sampled 09/22/93

Sampled By CLIENT

STANDARD LABORATORIE

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #2

GRINDABILITY MOISTURE = 2.52%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% S
As Rec'd.	12.52	10.39	33.75	43.34	11322	2.
Dry Basis	-----	11.88	38.58	49.54	12942	2.
M-A-Free					14687	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2150	2580
SOFTENING	2240	2610
HEMISPHERICAL	2385	2620
FINAL	2480	2635

HARDGROVE GRINDABILITY INDEX : 53

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No.	59018
Date Rec'd	09/27/93
Date Sampled	09/22/93
Sampled By	CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:
COAL FEEDER
TEST #2

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.88
HYDROGEN	4.99
CARBON	72.24
NITROGEN	1.57
SULFUR	2.48
OXYGEN	6.84
CHLORINE	<0.01

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	48.10
ALUMINUM OXIDE (AL2O3)	25.16
TITANIUM DIOXIDE (TIO2)	1.14
CALCIUM OXIDE (CAO)	1.70
POTASSIUM OXIDE (K2O)	1.94
MAGNESIUM OXIDE (MGO)	0.78
SODIUM OXIDE (NA2O)	0.32
PHOSPHORUS PENTOXIDE (P2O5)	0.28
FERRIC OXIDE (FE2O3)	16.62
SULFUR TRIOXIDE (SO3)	0.96
UNDETERMINED	3.00

BASE/ACID RATIO: 0.2871
LBS OF ASH/MILLION BTU: 9.18
SLAG VISCOSITY: 2570 DEG F. T250 POISE
FOULING INDEX: 0.0919 TYPE: LOW
SLAGGING INDEX: 0.7120 TYPE: MEDIUM
SILICA VALUE: 71.5774
% ALKALI AS NA2O: 0.1917

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59019

Date Rec'd 09/27/93

Date Sampled 09/22/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
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EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #3

GRINDABILITY MOISTURE = 2.49%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.63	10.41	33.90	43.06	11255	2.34
Dry Basis	-----	11.91	38.80	49.29	12882	2.68
M-A-Free					14624	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2125	2580
SOFTENING	2205	2600
HEMISPHERICAL	2315	2625
FINAL	2465	2635

HARDGROVE GRINDABILITY INDEX : 55

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

59019
Lab. No.

09/27/93
Date Rec'd

09/22/93
Date Sampled

CLIENT
Sampled By

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
TEST #3

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.91
HYDROGEN	4.97
CARBON	72.01
NITROGEN	1.48
SULFUR	2.68
OXYGEN	6.95
CHLORINE	0.02

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	47.60
ALUMINUM OXIDE (AL2O3)	25.44
TITANIUM DIOXIDE (TIO2)	1.14
CALCIUM OXIDE (CAO)	1.62
POTASSIUM OXIDE (K2O)	1.94
MAGNESIUM OXIDE (MGO)	0.76
SODIUM OXIDE (NA2O)	0.30
PHOSPHORUS PENTOXIDE (P2O5)	0.28
FERRIC OXIDE (FE2O3)	17.42
SULFUR TRIOXIDE (SO3)	0.94
UNDETERMINED	2.56

BASE/ACID RATIO: 0.2971
LBS OF ASH/MILLION BTU: 9.25
SLAG VISCOSITY: 2550 DEG F. T250 POISE
FOULING INDEX: 0.0891 TYPE: LOW
SLAGGING INDEX: 0.7962 TYPE: MEDIUM
SILICA VALUE: 70.6231
% ALKALI AS NA2O: 0.1898

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59020

Date Rec'd. 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #1

GRINDABILITY MOISTURE = 2.64%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.30	10.09	34.32	43.29	11371	2.46
Dry Basis	-----	11.50	39.13	49.37	12966	2.80
M-A-Free					14651	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2165	2550
SOFTENING	2245	2570
HEMISPHERICAL	2295	2585
FINAL	2350	2600

HARDGROVE GRINDABILITY INDEX : 52

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59020

Date Rec'd 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
TEST #1

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

ARSENIC = 6.47 ug/g ASH BASIS

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.50
HYDROGEN	4.91
CARBON	72.32
NITROGEN	1.49
SULFUR	2.80
OXYGEN	6.98
CHLORINE	0.03

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	45.20
ALUMINUM OXIDE (AL2O3)	24.30
TITANIUM DIOXIDE (TIO2)	1.04
CALCIUM OXIDE (CAO)	2.04
POTASSIUM OXIDE (K2O)	1.74
MAGNESIUM OXIDE (MGO)	0.70
SODIUM OXIDE (NA2O)	0.28
PHOSPHORUS PENTOXIDE (P2O5)	0.30
FERRIC OXIDE (FE2O3)	20.30
SULFUR TRIOXIDE (SO3)	1.13
UNDETERMINED	2.97

BASE/ACID RATIO: 0.3553
LBS OF ASH/MILLION BTU: 8.87
SLAG VISCOSITY: 2460 DEG F. T250 POISE
FOULING INDEX: 0.0995 TYPE: LOW
SLAGGING INDEX: 0.9948 TYPE: MEDIUM
SILICA VALUE: 66.2368
% ALKALI AS NA2O: 0.1657

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59021

Date Rec'd 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #2

GRINDABILITY MOISTURE = 2.57%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.36	9.48	34.09	43.07	11335	2.37
Dry Basis	-----	10.94	39.35	49.71	13083	2.74
M-A-Free					14690	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2170	2560
SOFTENING	2250	2575
HEMISPHERICAL	2345	2585
FINAL	2410	2600

HARDGROVE GRINDABILITY INDEX : 54

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59021

Date Rec'd 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
TEST #2

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	10.94
HYDROGEN	4.96
CARBON	72.86
NITROGEN	1.56
SULFUR	2.74
OXYGEN	6.94
CHLORINE	0.02

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	45.10
ALUMINUM OXIDE (AL2O3)	24.60
TITANIUM DIOXIDE (TIO2)	1.10
CALCIUM OXIDE (CAO)	2.04
POTASSIUM OXIDE (K2O)	1.74
MAGNESIUM OXIDE (MGO)	0.78
SODIUM OXIDE (NA2O)	0.30
PHOSPHORUS PENTOXIDE (P2O5)	0.28
FERRIC OXIDE (FE2O3)	19.94
SULFUR TRIOXIDE (SO3)	1.13
UNDETERMINED	2.99

BASE/ACID RATIO: 0.3503
LBS OF ASH/MILLION BTU: 8.36
SLAG VISCOSITY: 2470 DEG F. T250 POISE
FOULING INDEX: 0.1051 TYPE: LOW
SLAGGING INDEX: 0.9598 TYPE: MEDIUM
SILICA VALUE: 66.4604
% ALKALI AS NA2O: 0.1598

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59022

Date Rec'd 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #3

GRINDABILITY MOISTURE = 2.72%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.32	10.31	33.76	42.61	11189	1.86
Dry Basis	-----	11.90	38.95	49.15	12908	2.15
M-A-Free					14652	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2205	2595
SOFTENING	2300	2620
HEMISPHERICAL	2405	2635
FINAL	2505	2650

HARDGROVE GRINDABILITY INDEX : 54

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59022

Date Rec'd 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
TEST #3

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM NERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.90
HYDROGEN	4.90
CARBON	71.80
NITROGEN	1.41
SULFUR	2.15
OXYGEN	7.84
CHLORINE	<0.01

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO_2)	46.70
ALUMINUM OXIDE (AL_2O_3)	26.04
TITANIUM DIOXIDE (TIO_2)	1.14
CALCIUM OXIDE (CAO)	1.60
POTASSIUM OXIDE (K_2O)	2.06
MAGNESIUM OXIDE (MGO)	0.80
SODIUM OXIDE (NA_2O)	0.32
PHOSPHORUS PENTOXIDE (P_2O_5)	0.27
FERRIC OXIDE (FE_2O_3)	17.40
SULFUR TRIOXIDE (SO_3)	0.67
UNDETERMINED	3.00

BASE/ACID RATIO:	0.3002	
LBS OF ASH/MILLION BTU:	9.22	
SLAG VISCOSITY:	2550 DEG F. T250 POISE	
FOULING INDEX:	0.0961	TYPE: LOW
SLAGGING INDEX:	0.6454	TYPE: MEDIUM
SILICA VALUE:	70.2256	
% ALKALI AS NA_2O:	0.2016	

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59023

Date Rec'd 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
PM 10

GRINDABILITY MOISTURE = 2.72%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.98	10.02	33.30	42.70	11104	2.12
Dry Basis	-----	11.65	38.71	49.64	12909	2.47
M-A-Free					14611	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2295	2620
SOFTENING	2400	2635
HEMISPHERICAL	2485	2650
FINAL	2570	2665

HARDGROVE GRINDABILITY INDEX : 53

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59023

Date Rec'd 09/27/93

Date Sampled 09/23/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
PM 10

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.65
HYDROGEN	4.86
CARBON	72.17
NITROGEN	1.47
SULFUR	2.47
OXYGEN	7.38
CHLORINE	<0.01

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	47.90
ALUMINUM OXIDE (AL2O3)	26.20
TITANIUM DIOXIDE (TIO2)	1.12
CALCIUM OXIDE (CAO)	1.72
POTASSIUM OXIDE (K2O)	2.08
MAGNESIUM OXIDE (MGO)	0.86
SODIUM OXIDE (NA2O)	0.32
PHOSPHORUS PENTOXIDE (P2O5)	0.31
FERRIC OXIDE (FE2O3)	15.54
SULFUR TRIOXIDE (SO3)	0.95
UNDETERMINED	3.00

BASE/ACID RATIO: 0.2728
LBS OF ASH/MILLION BTU: 9.02
SLAG VISCOSITY: 2600 DEG F. T250 POISE
FOULING INDEX: 0.0873 TYPE: LOW
SLAGGING INDEX: 0.6738 TYPE: MEDIUM
SILICA VALUE: 72.5538
% ALKALI AS NA2O: 0.1989

Respectfully Submitted, Brett A. Stock

BRETT A. STOCK

Lab. No. 59024

Date Rec'd 09/27/93

Date Sampled 09/24/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #1

GRINDABILITY MOISTURE = 2.98%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.29	9.44	34.66	42.61	11314	2.32
Dry Basis	-----	10.89	39.97	49.14	13048	2.68
M-A-Free					14643	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2220	2615
SOFTENING	2370	2625
HEMISPHERICAL	2420	2640
FINAL	2495	2655

HARDGROVE GRINDABILITY INDEX : 50

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No.	59024
Date Rec'd	09/27/93
Date Sampled	09/24/93
Sampled By	CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:
COAL FEEDER
TEST #1

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

ARSENIC = 9.61 ug/g ASH BASIS

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	10.89
HYDROGEN	4.94
CARBON	72.57
NITROGEN	1.49
SULFUR	2.68
OXYGEN	7.43
CHLORINE	<0.01

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	45.70
ALUMINUM OXIDE (AL2O3)	25.98
TITANIUM DIOXIDE (TIO2)	1.08
CALCIUM OXIDE (CAO)	2.18
POTASSIUM OXIDE (K2O)	1.82
MAGNESIUM OXIDE (MGO)	0.78
SODIUM OXIDE (NA2O)	0.32
PHOSPHORUS PENTOXIDE (P2O5)	0.29
FERRIC OXIDE (FE2O3)	16.96
SULFUR TRIOXIDE (SO3)	1.88
UNDETERMINED	3.01

BASE/ACID RATIO: 0.3032
LBS OF ASH/MILLION BTU: 8.35
SLAG VISCOSITY: 2550 DEG F. T250 POISE
FOULING INDEX: 0.0970 TYPE: LOW
SLAGGING INDEX: 0.8126 TYPE: MEDIUM
SILICA VALUE: 69.6434
% ALKALI AS NA2O: 0.1670

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59025

Date Rec'd 09/27/93

Date Sampled 09/24/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #2

GRINDABILITY MOISTURE = 2.76%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.21	10.12	34.16	42.51	11213	2.16
Dry Basis	-----	11.66	39.36	48.98	12920	2.49
M-A-Free					14625	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2230	2645
SOFTENING	2375	2660
HEMISPHERICAL	2430	2675
FINAL	2490	2690

HARDGROVE GRINDABILITY INDEX : 51

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59025

Date Rec'd 09/27/93

Date Sampled 09/24/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
TEST #2

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.66
HYDROGEN	4.86
CARBON	72.16
NITROGEN	1.47
SULFUR	2.49
OXYGEN	7.36
CHLORINE	<0.01

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	49.20
ALUMINUM OXIDE (AL2O3)	26.38
TITANIUM DIOXIDE (TIO2)	1.10
CALCIUM OXIDE (CAO)	1.70
POTASSIUM OXIDE (K2O)	2.04
MAGNESIUM OXIDE (MGO)	0.80
SODIUM OXIDE (NA2O)	0.32
PHOSPHORUS PENTOXIDE (P2O5)	0.29
FERRIC OXIDE (FE2O3)	14.34
SULFUR TRIOXIDE (SO3)	0.87
UNDETERMINED	2.96

BASE/ACID RATIO: 0.2504
LBS OF ASH/MILLION BTU: 9.02
SLAG VISCOSITY: 2630 DEG F. T250 POISE
FOULING INDEX: 0.0801 TYPE: LOW
SLAGGING INDEX: 0.6235 TYPE: MEDIUM
SILICA VALUE: 74.5003
% ALKALI AS NA2O: 0.1960

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59026

Date Rec'd 09/27/93

Date Sampled 09/24/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
TEST #3

GRINDABILITY MOISTURE = 2.78%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.09	9.62	33.73	43.56	11373	2.09
Dry Basis	-----	11.07	38.81	50.12	13086	2.41
M-A-Free					14715	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2225	2590
SOFTENING	2355	2625
HEMISPHERICAL	2410	2645
FINAL	2505	2675

HARDGROVE GRINDABILITY INDEX : 51

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59026

Date Rec'd 09/27/93

Date Sampled 09/24/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:
COAL FEEDER
TEST #3

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.07
HYDROGEN	4.97
CARBON	73.03
NITROGEN	1.57
SULFUR	2.41
OXYGEN	6.95
CHLORINE	0.02

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	49.00
ALUMINUM OXIDE (AL2O3)	25.98
TITANIUM DIOXIDE (TIO2)	1.18
CALCIUM OXIDE (CAO)	1.96
POTASSIUM OXIDE (K2O)	2.02
MAGNESIUM OXIDE (MGO)	0.84
SODIUM OXIDE (NA2O)	0.30
PHOSPHORUS PENTOXIDE (P2O5)	0.26
FERRIC OXIDE (FE2O3)	15.04
SULFUR TRIOXIDE (SO3)	1.11
UNDETERMINED	2.31

BASE/ACID RATIO: 0.2647
LBS OF ASH/MILLION BTU: 8.46
SLAG VISCOSITY: 2620 DEG F. T250 POISE
FOULING INDEX: 0.0794 TYPE: LOW
SLAGGING INDEX: 0.6379 TYPE: MEDIUM
SILICA VALUE: 73.3094
% ALKALI AS NA2O: 0.1824

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59027

Date Rec'd 09/27/93

Date Sampled 09/24/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL FEEDER
PM 10

GRINDABILITY MOISTURE = 2.89%

DATE REPORTED: 10/08/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.71	10.24	33.31	42.74	11112	2.13
Dry Basis	-----	11.87	38.60	49.53	12877	2.47
M-A-Free					14611	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2230	2610
SOFTENING	2360	2640
HEMISPHERICAL	2415	2660
FINAL	2500	2695

HARDGROVE GRINDABILITY INDEX : 53

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 59027

Date Rec'd 09/27/93

Date Sampled 09/24/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL FEEDER
PM 10

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 10/08/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.87
HYDROGEN	4.95
CARBON	72.00
NITROGEN	1.56
SULFUR	2.47
OXYGEN	7.15
CHLORINE	0.03

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	49.20
ALUMINUM OXIDE (AL2O3)	25.60
TITANIUM DIOXIDE (TIO2)	1.16
CALCIUM OXIDE (CAO)	1.70
POTASSIUM OXIDE (K2O)	2.12
MAGNESIUM OXIDE (MGO)	0.84
SODIUM OXIDE (NA2O)	0.32
PHOSPHORUS PENTOXIDE (P2O5)	0.28
FERRIC OXIDE (FE2O3)	15.10
SULFUR TRIOXIDE (SO3)	0.93
UNDETERMINED	2.75

BASE/ACID RATIO: 0.2643
LBS OF ASH/MILLION BTU: 9.22
SLAG VISCOSITY: 2620 DEG F. T250 POISE
FOULING INDEX: 0.0846 TYPE: LOW
SLAGGING INDEX: 0.6528 TYPE: MEDIUM
SILICA VALUE: 73.6086
% ALKALI AS NA2O: 0.2058

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 62226

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

STACK TEST
#1
LIFAC DEMONSTRATION

DATE REPORTED: 12/16/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.65	9.73	32.96	44.66	11356	2.32
Dry Basis	-----	11.14	37.73	51.13	13001	2.66
M-A-Free					14631	

Respectfully Submitted,

Lab. No. 62227

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

STACK TEST
#2
LIFAC DEMONSTRATION

DATE REPORTED: 12/16/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.29
HYDROGEN	4.88
CARBON	72.87
NITROGEN	1.49
SULFUR	2.56
OXYGEN	6.91

Respectfully Submitted,

Lab. No. 62228

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

STACK TEST
#3
LIFAC DEMONSTRATION

DATE REPORTED: 12/16/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.62	10.01	33.63	43.74	11334	2.33
Dry Basis	-----	11.45	38.49	50.06	12971	2.67
M-A-Free					14648	

Respectfully Submitted,

Lab. No. 62228

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

STACK TEST
#3
LIFAC DEMONSTRATION

DATE REPORTED: 12/16/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.45
HYDROGEN	4.85
CARBON	73.31
NITROGEN	1.44
SULFUR	2.67
OXYGEN	6.28

Respectfully Submitted,

Lab. No. 62229

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

STACK TEST
#4
LIFAC DEMONSTRATION

DATE REPORTED: 12/16/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.18	9.55	33.21	45.06	11505	2.06
Dry Basis	-----	10.87	37.82	51.31	13101	2.35
M-A-Free					14699	

Respectfully Submitted,

Lab. No. 62229

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

STACK TEST
#4
LIFAC DEMONSTRATION

DATE REPORTED: 12/16/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	10.87
HYDROGEN	4.82
CARBON	73.62
NITROGEN	1.43
SULFUR	2.35
OXYGEN	6.91

Respectfully Submitted,

Lab. No. 62322

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

LIFAC DEMONSTRATION
PROJ. NO. 91001
CHAIN OF CUSTODY RECORD #5353
DAILY COMPOSITE 12/07/93
LAB-GENERATED COMPOSITE

ARSENIC (As) = 12.1 ug/g DRY COAL BASIS
FLUORINE (F) = 48.3 ug/g DRY COAL BASIS
CHLORINE = 0.04% DRY BASIS
GRINDABILITY MOISTURE = 2.23%
DATE REPORTED: 12/30/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.49	9.79	XXXX	XXXX	11390	2.24
Dry Basis	-----	11.19	XXXX	XXXX	13016	2.56
M-A-Free					14656	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2165	2525
SOFTENING	2275	2535
HEMISPHERICAL	2385	2545
FINAL	2460	2555

HARDGROVE GRINDABILITY INDEX( ) : 50

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

Lab. No. 62322

Date Rec'd 12/08/93

Date Sampled 12/07/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:
LIFAC DEMONSTRATION
PROJ. NO. 91001
CHAIN OF CUSTODY RECORD #5353

DAILY COMPOSITE 12/07/93
LAB-GENERATED COMPOSITE

DATE REPORTED: 12/30/93

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	47.72
ALUMINUM OXIDE (AL2O3)	23.68
TITANIUM DIOXIDE (TIO2)	0.99
CALCIUM OXIDE (CAO)	1.57
POTASSIUM OXIDE (K2O)	1.67
MAGNESIUM OXIDE (MGO)	0.72
SODIUM OXIDE (NA2O)	0.44
PHOSPHORUS PENTOXIDE (P2O5)	0.29
FERRIC OXIDE (FE2O3)	21.89
SULFUR TRIOXIDE (SO3)	1.03
UNDETERMINED	0.00

BASE/ACID RATIO: 0.3631
LBS OF ASH/MILLION BTU: 8.60
SLAG VISCOSITY: 2460 DEG F. T250 POISE
FOULING INDEX: 0.1588 TYPE: LOW
SLAGGING INDEX: 0.9295 TYPE: MEDIUM
SILICA VALUE: 66.3717
% ALKALI AS NA2O: 0.1736

Respectfully Submitted,

Lab. No. 62273

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

STACK TEST
#1
LIFAC DEMONSTRATION

DATE REPORTED: 12/20/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.53	9.71	34.59	43.17	11431	2.24
Dry Basis	-----	11.10	39.55	49.35	13069	2.56
M-A-Free					14701	

Respectfully Submitted,

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

Lab. No. 62273
Date Rec'd 12/09/93
Date Sampled 12/08/93
Sampled By CLIENT

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

SAMPLE ID:

STACK TEST
#1
LIFAC DEMONSTRATION

DATE REPORTED: 12/21/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.10
HYDROGEN	4.95
CARBON	73.10
NITROGEN	1.48
SULFUR	2.56
OXYGEN	6.81

Respectfully Submitted,

Lab. No. 62274

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

STACK TEST
#2
LIFAC DEMONSTRATION

DATE REPORTED: 12/20/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.76	9.75	34.36	43.13	11373	2.18
Dry Basis	-----	11.18	39.38	49.44	13037	2.50
M-A-Free					14678	

Respectfully Submitted,

Lab. No. 62274

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

STACK TEST
#2
LIFAC DEMONSTRATION

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

DATE REPORTED: 12/21/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	11.18
HYDROGEN	4.88
CARBON	73.30
NITROGEN	1.46
SULFUR	2.50
OXYGEN	6.68

Respectfully Submitted,

Lab. No. 62275

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

STACK TEST
#3
LIFAC DEMONSTRATION

DATE REPORTED: 12/20/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.96	9.34	33.62	44.08	11440	2.10
Dry Basis	-----	10.73	38.63	50.64	13143	2.41
M-A-Free					14723	

Respectfully Submitted,

Lab. No. 62275

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

STACK TEST
#3
LIFAC DEMONSTRATION

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

DATE REPORTED: 12/21/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	10.73
HYDROGEN	4.88
CARBON	74.02
NITROGEN	1.48
SULFUR	2.41
OXYGEN	6.48

Respectfully Submitted,

Lab. No. 62276

Date Rec'd. 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

STACK TEST
#4
LIFAC DEMONSTRATION

DATE REPORTED: 12/20/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.97	9.33	33.06	44.64	11423	2.03
Dry Basis	-----	10.72	37.99	51.29	13125	2.33
M-A-Free					14701	

FOR YOUR PROTECTION THIS DOCUMENT HAS BEEN PRINTED ON CONTROLLED PAPER STOCK. NOT VALID IF ALTERED.

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 62276

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

STACK TEST
#4
LIFAC DEMONSTRATION

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

DATE REPORTED: 12/21/93

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	10.72
HYDROGEN	4.85
CARBON	74.40
NITROGEN	1.51
SULFUR	2.33
OXYGEN	6.19

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 62323

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

LIFAC DEMONSTRATION
PROJ. NO. 91001
CHAIN OF CUSTODY RECORD #5355
DAILY COMPOSITE 12/08/93
LAB-GENERATED COMPOSITE

ARSENIC (As) = 13.0 ug/g DRY COAL BASIS
FLUORINE (F) = 45.8 ug/g DRY COAL BASIS
CHLORINE = 0.04% DRY BASIS
GRINDABILITY MOISTURE = 2.11
DATE REPORTED: 12/30/93

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.81	9.53	XXXX	XXXX	11417	2.14
Dry Basis	-----	10.93	XXXX	XXXX	13094	2.45
M-A-Free					14701	

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2175	2550
SOFTENING	2310	2575
HEMISPHERICAL	2410	2600
FINAL	2490	2620

HARDGROVE GRINDABILITY INDEX( ) : 51

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 62323

Date Rec'd 12/09/93

Date Sampled 12/08/93

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN.: MR. JIM HERVOL

SAMPLE ID: LIFAC DEMONSTRATION
PROJ. NO. 91001
CHAIN OF CUSTODY RECORD #5355

DAILY COMPOSITE 12/08/93
LAB-GENERATED COMPOSITE

DATE REPORTED: 12/30/93

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	49.17
ALUMINUM OXIDE (AL2O3)	23.86
TITANIUM DIOXIDE (TIO2)	0.96
CALCIUM OXIDE (CAO)	1.67
POTASSIUM OXIDE (K2O)	1.61
MAGNESIUM OXIDE (MGO)	0.63
SODIUM OXIDE (NA2O)	0.47
PHOSPHORUS PENTOXIDE (P2O5)	0.27
FERRIC OXIDE (FE2O3)	20.28
SULFUR TRIOXIDE (SO3)	1.07
UNDETERMINED	0.00

BASE/ACID RATIO: 0.3333
LBS OF ASH/MILLION BTU: 8.35
SLAG VISCOSITY: 2490 DEG F. T250 POISE
FOULING INDEX: 0.1573 TYPE: LOW
SLAGGING INDEX: 0.8166 TYPE: MEDIUM
SILICA VALUE: 68.5307
% ALKALI AS NA2O: 0.1692

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 73653

Date Rec'd. 05/18/94

Date Sampled 05/17/94

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL SAMPLE FROM STA. #1

DATE REPORTED: 06/02/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.66	8.04	34.55	43.75	11368	2.24
Dry Basis	-----	9.32	40.01	50.67	13167	2.59
M-A-Free					14519	
Method						

FOR YOUR PROTECTION THIS DOCUMENT HAS BEEN PRINTED ON CONTROLLED PAPER STOCK. NOT VALID IF ALTERED

Respectfully Submitted,

BRETT STOCK

Lab. No. 73658

Date Rec'd 05/18/94

Date Sampled 05/17/94

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID.
COAL SAMPLE FROM STA. #1

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 06/02/94

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	9.32
HYDROGEN	5.11
CARBON	74.32
NITROGEN	1.53
SULFUR	2.59
OXYGEN	7.13

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 73659

Date Rec'd. 05/18/94

Date Sampled 05/17/94

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL SAMPLE FROM STA. #2

DATE REPORTED: 06/02/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.70	8.22	34.71	43.37	11343	2.15
Dry Basis	-----	9.53	40.22	50.25	13143	2.49
M-A-Free					14527	
Method						

Respectfully Submitted,

BRETT STOCK

Lab. No. 73659

Date Rec'd. 05/18/94

Date Sampled 05/17/94

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: COAL SAMPLE FROM STA. #2

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 06/02/94

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	9.53
HYDROGEN	5.06
CARBON	74.17
NITROGEN	1.43
SULFUR	2.49
OXYGEN	7.32

Respectfully Submitted,

BRETT A. STOCK

Lab. No. 73660

Date Rec'd. 05/18/94

Date Sampled 05/17/94

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COAL SAMPLE FROM STA. #3

DATE REPORTED: 06/02/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.79	8.11	34.72	43.38	11432	2.07
Dry Basis	-----	9.41	40.27	50.32	13261	2.40
M-A-Free					14638	
Method						

Respectfully Submitted,

BRETT STOCK

Lab. No. 73660

Date Rec'd 05/18/94

Date Sampled 05/17/94

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID
COAL SAMPLE FROM STA. #3

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 06/02/94

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	9.41
HYDROGEN	5.03
CARBON	74.07
NITROGEN	1.52
SULFUR	2.40
OXYGEN	7.57

Respectfully Submitted,

BRETT A. STOCK

Lab. No.	73661
Date Rec'd.	05/18/94
Date Sampled	05/17/94
Sampled By	CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

COMPOSITE OF STA. #1,2,&3

CHLORINE = <0.01% DRY COAL BASIS
FLUORINE = 43.6 UG/G DRY COAL BASIS
ARSENIC = 7.84 UG/G DRY COAL BASIS

DATE REPORTED: 06/10/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.46	8.27	XXXX	XXXX	11487	2.12
Dry Basis	-----	9.56	XXXX	XXXX	13274	2.45
M-A-Free					14677	
Method						

FREE SWELLING INDEX : XXXX

ASH FUSION TEMPERATURES (DEG F)	REDUCING	OXIDIZING
INITIAL	2080	2495
SOFTENING	2200	2515
HEMISPHERICAL	2305	2540
FINAL	2375	2570

HARDGROVE GRINDABILITY INDEX : 50 @ 3.22 % MOISTURE

NOTE: XXXX INDICATES ANALYSIS WAS NOT PERFORMED

Respectfully Submitted,

BRETT STOCK

Lab. No. 73661

Date Rec'd. 05/18/94

Date Sampled 05/17/94

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

COMPOSITE OF STA. #1,2,&3

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

DATE REPORTED: 06/10/94

MINERAL ANALYSIS OF ASH	% IGNITED BASIS
SILICON DIOXIDE (SIO2)	39.48
ALUMINUM OXIDE (AL203)	24.31
TITANIUM DIOXIDE (TIO2)	0.99
CALCIUM OXIDE (CAO)	3.10
POTASSIUM OXIDE (K20)	1.70
MAGNESIUM OXIDE (MGO)	0.59
SODIUM OXIDE (NA20)	0.45
PHOSPHORUS PENTOXIDE (P205)	0.42
FERRIC OXIDE (FE203)	26.30
SULFUR TRIOXIDE (SO3)	2.66
UNDETERMINED	0.00

BASE/ACID RATIO: 0.4962
LBS OF ASH/MILLION BTU: 7.20
SLAG VISCOSITY: 2310 DEG F. T250 POISE
FOULING INDEX: 0.2252 TYPE: MEDIUM
SLAGGING INDEX: 1.2157 TYPE: MEDIUM
SILICA VALUE: 56.8304
% ALKALI AS NA2O: 0.1516

Respectfully Submitted, Brett A. Stock

BRETT A. STOCK

Lab. No. 78152

Date Rec'd. 08/18/94

Date Sampled --------

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

ST #1
STACK TEST 1
08/16/94

DATE REPORTED: 09/08/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.07	8.91	35.75	42.27	11429	2.29
Dry Basis	-----	10.25	41.12	48.63	13147	2.64
M-A-Free					14648	
Method						

Respectfully Submitted, Brett Stock, TC

BRETT STOCK

Lab. No. 78152

Date Rec'd 08/18/94

Date Sampled -------

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

ST #1
STACK TEST #1
08/16/94

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1507
ATTN: MR. JIM HERVOL

DATE REPORTED: 09/08/94

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	10.25
HYDROGEN	5.17
CARBON	73.21
NITROGEN	1.67
SULFUR	2.64
OXYGEN	7.06

Respectfully Submitted, Brett Stork, TC

Lab. No. 78153

Date Rec'd. 08/18/94

Date Sampled ---------

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

ST #2
STACK TEST #2
08/16/94

DATE REPORTED: 09/08/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.28	8.34	35.66	42.72	11578	2.36
Dry Basis	-----	9.61	41.12	49.27	13352	2.72
M-A-Free					14772	
Method						

Respectfully Submitted, Brett Stock TC

BRETT STOCK

78153
Lab. No.

08/18/94
Date Rec'd

Date Sampled

CLIENT
Sampled By

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: ST #2
STACK TEST #2
08/16/94

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1507
ATTN: MR. JIM HERVOL

DATE REPORTED: 09/08/94

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	9.61
HYDROGEN	5.14
CARBON	73.74
NITROGEN	1.65
SULFUR	2.72
OXYGEN	7.14

Respectfully Submitted, Brett Stock TC

BRETT A. STOCK

Lab. No. 78154

Date Rec'd. 08/18/94

Date Sampled --------

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

ST #3
STACK TEST #3
08/16/94

DATE REPORTED: 09/08/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	13.01	8.61	36.33	42.05	11500	2.36
Dry Basis	-----	9.90	41.76	48.34	13220	2.72
M-A-Free					14673	
Method						

Respectfully Submitted, Brett Stock TC

Lab. No. 78154

Date Rec'd 08/18/94

Date Sampled -------

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID:

ST #3
STACK TEST #3
08/16/94

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1507
ATTN: MR. JIM HERVOL

DATE REPORTED: 09/08/94

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	9.90
HYDROGEN	5.14
CARBON	73.42
NITROGEN	1.65
SULFUR	2.72
OXYGEN	7.17

Respectfully Submitted, Brett Stock TC

Lab. No. 78155

Date Rec'd. 08/18/94

Date Sampled --------

Sampled By CLIENT

STANDARD LABORATORIES, INC.
1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1207
ATTN: MR. JIM HERVOL

SAMPLE IDENTIFICATION

ST #4
STACK TEST #4
08/16/94

DATE REPORTED: 09/08/94

	% Moisture	% Ash	% Volatile	% Fixed Carbon	B.T.U./LB.	% Sulfur
As Rec'd.	12.98	8.60	36.27	42.15	11546	2.33
Dry Basis	-----	9.88	41.68	48.44	13269	2.68
M-A-Free					14723	
Method						

Respectfully Submitted, Brett Stock

Lab. No. 78155

Date Rec'd 08/18/94

Date Sampled ------

Sampled By CLIENT

STANDARD LABORATORIES, INC.

1530 N. CULLEN AVENUE
EVANSVILLE, IN 47715

SAMPLE ID: ST #4
STACK TEST #4
08/16/94

ICF KAISER ENGINEERING
4 GATEWAY CENTER
PITTSBURGH, PA 15222-1507
ATTN: MR. JIM HERVOL

DATE REPORTED: 09/08/94

ULTIMATE ANALYSIS OF COAL	% DRY BASIS
ASH	9.88
HYDROGEN	5.19
CARBON	73.53
NITROGEN	1.68
SULFUR	2.68
OXYGEN	7.04

Respectfully Submitted, Brett Stock TC

BRETT A. STOCK

APPENDIX II

LIMESTONE ANALYSIS

LABORATORY TESTS RESULTS
02/14/94

JOB NUMBER: 932413 CUSTOMER: ICF KAISER ENGINEERS ATTN: JIM HERVOL

CLIENT I.D.........: LIFAC DEMONSTRATION
DATE SAMPLED.......: 12/07/93
TIME SAMPLED.......: :
WORK DESCRIPTION...: LIMESTONE DAILY SAMPLED

LABORATORY I.D...: 932413-0001
DATE RECEIVED....: 12/14/93
TIME RECEIVED....: 12:00
REMARKS..........: CLIENT SAMPLED

TEST DESCRIPTION	FINAL RESULT	DETECTION LIMITS	UNITS OF MEASURE	TEST METHOD	DATE	TECHNICIAN
Free Moisture in Limestone	<0.01	0.01	%	ASTM C 25-20	02/09/94	DSK
Calcium Carbonate	83.2	0.01	%	ASTM C 25	02/09/94	DSK
Passing 200 mesh	96.58	0.01	% by wt.	ASTM D4749	02/02/94	BAS
Magnesium Carbonate	10.6	0.01	%	ASTM C 25	02/09/94	DSK
Silicon Dioxide	3.91	0.01	%		02/03/94	DSK
Passing 325 mesh	90.35	0.01	% by wt.	ASTM D4749	02/02/94	BAS
Aluminum Oxide	0.34	0.01	%		02/03/94	DSK
Sodium Oxide	0.20	0.01	%		02/03/94	DSK

APPROVED BY: Judith Snider

2315 Glenview Drive
Evansville, IN 47720
(812) 424-2909

Q U A L I T Y   A S S U R A N C E   R E P O R T
02/14/94

JOB NUMBER: 932418   CUSTOMER: ICF KAISER ENGINEERS   ATTN: JIM HERVOL

ANALYSIS				DUPLICATES		REFERENCE STANDARDS		MATRIX SPIKES		
ANALYSIS TYPE	ANALYSIS SUB-TYPE	ANALYSIS I.D.	ANALYZED VALUE (A)	DUPLICATE VALUE (B)	RPD or (|A-B|)	TRUE VALUE	PERCENT RECOVERY	ORIGINAL VALUE	SPIKE ADDED	PERCENT RECOVERY
PARAMETER:Silicon Dioxide DETECTION LIMIT:0.01 UNITS:%				DATE/TIME ANALYZED:02/03/94 12:30 METHOD REFERENCE :				QC BATCH NUMBER:940725 TECHNICIAN:DSK		
BLANK	Reagent	Blank	0.6							
STANDARD	Analytical	ICP4 1:100	1.1			1.0	110			
DUPLICATE	Analytical	932277-1	29.5	29.5	0					
PARAMETER:Sodium Oxide DETECTION LIMIT:0.01 UNITS:%				DATE/TIME ANALYZED:02/03/94 12:56 METHOD REFERENCE :				QC BATCH NUMBER:940726 TECHNICIAN:DSK		
BLANK	Reagent	Blank	1.8							
BLANK	Reagent	Blank	1.5							
STANDARD	Analytical	ICP 2	9.8			10.0	98			
STANDARD	Analytical	ICP 2	9.9			10.0	99			
SPIKE	Analytical	940168-2	41.6					30.4	10.0	112
SPIKE	Analytical	940171-1	39.4					30.8	10.0	86
DUPLICATE	Analytical	940168-1	609	609	0					
DUPLICATE	Analytical	940171-1	30.8	31.0	0.65					
DUPLICATE	Analytical	932277-1	0.34	0.34	0					
PARAMETER:Aluminum Oxide DETECTION LIMIT:0.01 UNITS:%				DATE/TIME ANALYZED:02/03/94 11:00 METHOD REFERENCE :				QC BATCH NUMBER:940727 TECHNICIAN:DSK		
BLANK	Reagent	Blank	0.12							
STANDARD	Analytical	APG 7878	0.06			0.06	100			
STANDARD	Analytical	ERA 9947	0.16			0.20	80			
DUPLICATE	Analytical	932277-1	2.89	2.67	7.91					
PARAMETER:Passing 200 mesh DETECTION LIMIT:0.01 UNITS:% by wt.				DATE/TIME ANALYZED:02/02/94 : METHOD REFERENCE :				QC BATCH NUMBER:940863 TECHNICIAN:BAS		

APPROVED BY: Judith Snider

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Evansville, IN 47720
(812) 424-2909

NC = Not Calculable Due To Lower Than The Detection Limit

Quality Control Acceptance Criteria:
- Blanks .... Analyzed Value =/< Detection Limit
- Reference Standards 100 +/- 10 Percent Recovery
- Duplicates .... 20 Percent Relative Difference, or +/- Detection Limit
- Spikes .... 100 +/-- 25 Percent Recovery

Note: Data Reported In QA Report May Be Lower Than Value On Sample Data Page Due To Dilution Of Sample Into Analytical Range

QUALITY ASSURANCE REPORT
02/14/94

JOB NUMBER: 932418 CUSTOMER: ICF KAISER ENGINEERS ATTN: JIM HERVOL

ANALYSIS				DUPLICATES		REFERENCE STANDARDS		MATRIX SPIKES		
ANALYSIS TYPE	ANALYSIS SUB-TYPE	ANALYSIS I.D.	ANALYZED VALUE (A)	DUPLICATE VALUE (B)	RPD or (|A-B|)	TRUE VALUE	PERCENT RECOVERY	ORIGINAL VALUE	SPIKE ADDED	PERCENT RECOVERY
PARAMETER:Passing 325 mesh DETECTION LIMIT:0.01 UNITS:% by wt.			DATE/TIME ANALYZED:02/02/94 : METHOD REFERENCE :					QC BATCH NUMBER:940864 TECHNICIAN:BAS		
PARAMETER:Free Moisture in Limestone DETECTION LIMIT: UNITS:%			DATE/TIME ANALYZED:02/09/94 08:15 METHOD REFERENCE :ASTM C 25-20					QC BATCH NUMBER:940886 TECHNICIAN:DSK		
DUPLICATE DUPLICATE	Analytical	932418-1 -	0.00	0.00	0					
PARAMETER:Magnesium Carbonate DETECTION LIMIT:0.01 UNITS:%			DATE/TIME ANALYZED:02/09/94 14:40 METHOD REFERENCE :ASTM C 25					QC BATCH NUMBER:940900 TECHNICIAN:DSK		
STANDARD	Analytical	NBS Lime	0.92			0.88	104.55			
DUPLICATE	Analytical	932418-1	10.6	10.6	0					
DUPLICATE	Analytical	940228-1	1.14	0.91	22.44					
PARAMETER:Calcium Carbonate DETECTION LIMIT:0.01 UNITS:%			DATE/TIME ANALYZED:02/09/94 12:20 METHOD REFERENCE :ASTM C 25					QC BATCH NUMBER:940901 TECHNICIAN:DSK		
STANDARD	Analytical	NBS Lime	90.3			89.8	100.56			
DUPLICATE	Analytical	940228-1	95.9	97.0	1.14					

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- Reference Standards 100 +/- 10 Percent Recovery
- Duplicates .... 20 Percent Relative Difference, or +/- Detection Limit
- Spikes .... 100 +/-- 25 Percent Recovery

Note: Data Reported In QA Report May Be Lower Than Value On Sample Data Page Due To Dilution Of Sample Into Analytical Range